Baseline Survey of Tamar Estuary Shoreline Banks

Report prepared for NRM North – May 2007

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Executive Summary

As part of an interdisciplinary study investigating the potential impacts of the wide-scale eradication of *Spartina anglica* (Rice Grass), an intertidal surveying program has been established to enable the assessment of the morphology and stability of *Spartina* marshes throughout the Tamar Estuary, Tasmania. Erosional scarps have developed in the past few years, on the outer margins of marshes and in high water banks, indicating that sediment banks are retreating. This gives downstream consequences of increased turbidity in the water column, and perhaps re-deposition of sediment elsewhere.

The primary objective of this report is to provide baseline data and to facilitate the continuation of the Tamar Estuary intertidal surveying program, which will provide an understanding of the medium and long term process acting on intertidal banks, and allow for the timely implementation of appropriate management strategies.

This report provides details of the methodology used in this baseline survey as well as maps to assist in the location of survey benchmarks for future maintenance and re-surveying. Baseline survey profiles are also detailed to show the type of information that can be obtained. General comments and recommendations on major findings are briefly discussed.

Results show that two main marsh morphologies exist within the Tamar Estuary, differentiated from each other by edge type and the extent of vertical development. Outer margins of marshes in the upper estuary are most susceptible to erosional processes. Retreat of the outer edge of *Spartina* marshes has accelerated in the past 17 years, most likely resulting from an increase in recreational boating in the Tamar Estuary and possible changes in climatic conditions such as increased incidences of extreme weather events.

Erosion of high water banks both landward of *Spartina* marshes and where marshes are absent is also of concern. Erosion of these landforms is likely to be contributed to by, if not caused by non-marine erosional processes such as groundwater ‘sapping’. Detailed geomorphologic assessment of these landforms and associate erosional processes is required to enable appropriate future management.

Cross-sectional profiles facilitate the assessment of the long-term stability of marshes. It is recommended that the profiles be re-measured every five years to allow quantification of long term change in marsh morphology and stability, to provide to appropriate management objectives.

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1 Introduction

1.1 Background

The Tamar Estuary extends some 71 km inland from Bass Strait through to its tidal limit at the city of Launceston. It is well supplied with sediment from the South and North Esk Rivers, which, in the narrow and poorly flushed estuary tend to accumulate as fine-grained silt deposits in the upper reaches of the system both within the channel and on adjacent mudflats and shoals. This has been enhanced in recent decades by the introduction of the intertidal salt-marsh species *Spartina anglica* (rice grass or cord grass).

Much of the Tamar Estuary is now fringed by extensive S*partina anglica* marshes, the development of which has been described by Phillips (1975) and Pringle (1993). Sediment bank development and erosional processes within *Spartina* marshes has received a significant amount of attention in the international literature (Ranwell, 1964; Phillips, 1975; Lee and Partridge, 1983; Gray et al., 1991; Chung, 1993; Pringle, 1993; Kirby, 1994; Cahoon et al., 1996; Daehler and Strong, 1996; Zhang et al., 2004; Bouma, 2005a; Bouma, 2005b; Strong and Ayres, in press) proving an understanding of marsh development and erosional styles. Long term monitoring of Spartina marshes within the Tamar will allow inferences to be made on bank stability and erosional processes of the Tamar. This report details relevant data from a recent PhD project titled '*The potential consequences of the wide-scale eradication of Spartina anglica from the Tamar Estuary Tasmania*', in which a comprehensive intertidal surveying program was established.

While surface elevation increase has occurred within *Spartina* marshes resulting from sediment accretion (Pringle, 1993), erosion scarps have developed and have been observed in the outer margins within the last few years (Watchorn, 2000; Gill and Blake, 2002), illustrated in Fig. 1. A Scarp or cliff in a sedimentary area indicates a threshold change in significant erosion. These scarps indicate that the sediment banks are retreating, with downstream consequences of increased turbidity in the water column, and perhaps re-deposition of sediment elsewhere.

Gill and Blake (2002) produced a low budget report for the Tamar NRM, which aimed to assess the cause and extent of erosion identified by Watchorn (2000). As reported to the Tamar NRM Management Committee by Ellison (2002) the report had some strong

limitations, as a result of employing a very qualitative methodology which relied largely on distant photographic records. Consequently the report was therefore unable to be used to compare and assess future change. Ellison (2002) explained that monitoring of erosion could be best achieved through a detailed baseline topographic survey, where a cross-sectional profile measurement is obtained from the intertidal surface.

Increasing concerns over the likely effects of global sea level rise along with the expansion of population centres along coastlines has heightened international interest in the controls on vertical growth of salt marshes, and the role of marshes in coastal protection (Kirby, 1992; Kirby, 2000; Schwimmer and Pizzuto, 2000; Schwimmer, 2001; Kirby, 2002; van der Wal, 2002; Smith et al., 2004). Cross sectional profiles of intertidal zone assist in the description and assessment of morphological condition of marshes and high-water banks and have been used extensively for this purpose. Kirby (1992) showed that cross-sectional shape of mudflats directly relates to their erosional or depositional state. Profiles from the Humber, Medway, Wash and Severn Estuaries were compiled from both hydrographic and aerial surveys, showing that accretional banks exhibit a high, convex-upward profile, while erosional banks are relatively low and concave-upward. Schwimmer (2001) showed the correlation that exists between wave energy, sediment erosion rate and the resultant erosion styles of six marsh lagoon shorelines in Rehoboth Bay, Delaware, U.S.A. From this a predictive model of shoreline erosion was developed.

Total stations are commonly used for this type of application (Keim et al., 1999; Neira et al., 2005), producing high resolution and relatively low cost topographic data. If surveys are related to a known position and elevation, they can be repeated over time for quantitative evaluation of temporal change in marsh extent, surface elevation and morphology. The Launceston City Council has surveyed bed of the upper estuary from which change to channel depths can be determined. However these do not extend above low tide mark as their purpose is for monitoring to assessing dredge requirements between Tee Tree Bend and Kings wharf.

The primary objective of this report is to facilitate the continuation of the Tamar Estuary intertidal surveying program by providing details of the methodology used in this baseline survey as well as maps to assist in the location of survey benchmarks for future maintenance and re-surveying. Preliminary profiles for these locations are provided primarily to show the type of information that can be obtained. General comments on major findings are briefly discussed; however, detailed discussions of findings are not included. These can be found in the PhD thesis, which will be made available to NRM North at the completion of the project.

2 Materials and Methods

2.1 Study Site

A total of 20 transects were established across the intertidal zone approximately every 2 kilometres throughout the *Spartina*-affected sectors of the Tamar Estuary, adjusted where possible to the centre of local embayments (Figure 2.1). Reconnaissance studies suggested that this arbitrary distance was sufficient to account for the morphological variability of the intertidal zone throughout the estuary, and therefore yield a reliable data set from which the intertidal morphology could be described. Transect locations shown in Figure 2.1 in black and red are where benchmarks were established and baseline surveys were completed. Additionally, red Transects occur at the three earlier surveys established by the Port of Launceston and monitored between 1972 and 1989 by Phillips (1975) and Pringle (1993). These were located and resurveyed to provide a comparative temporal study of morphologic development and topographical change. Transect locations shown in green were established and benchmarks with coordinates but have not been surveyed to date, however could included in future surveys.

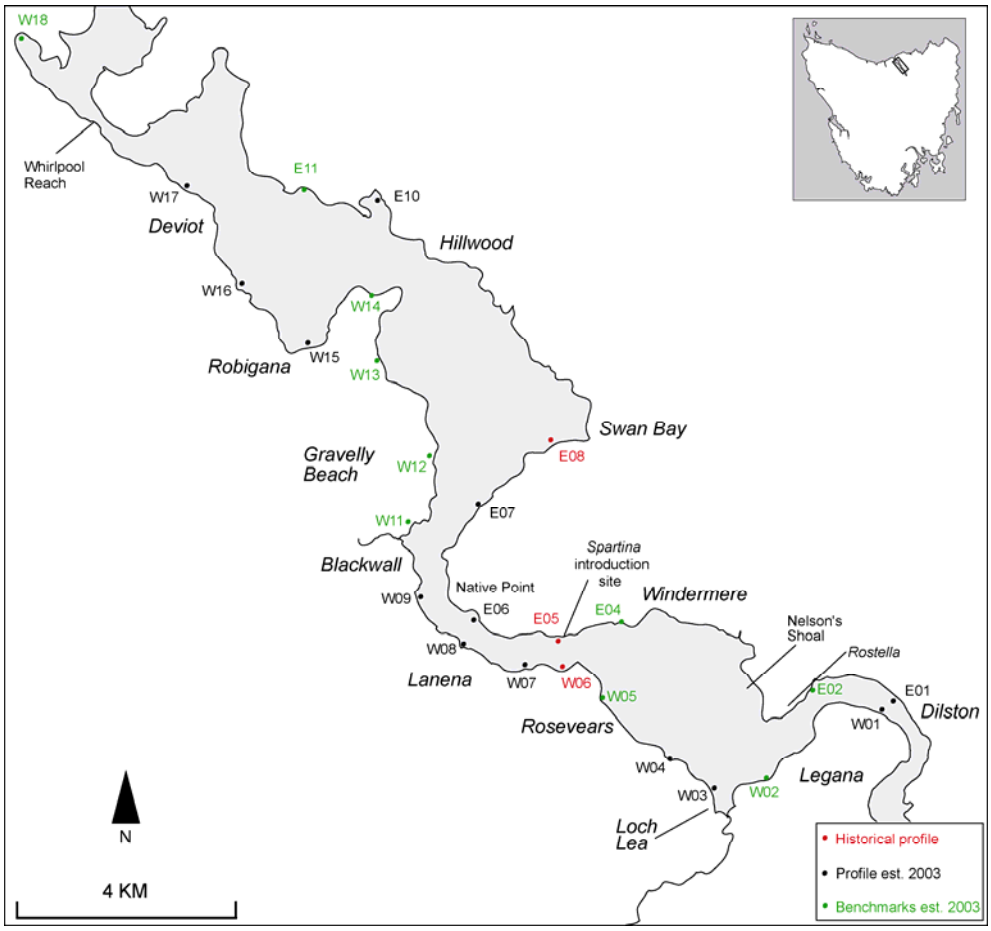


Figure 2.1: Locality map showing the position of surveyed transects throughout the Tamar Estuary.

2.2 Benchmarking

Benchmarking is necessary for the survey transect to be found again in the future for the purpose of resurveying. It is also necessary to relate each survey profile to a common datum such as absolute mean sea level, and benchmarking allows this. Existing survey control data within view of the Tamar coastline were inadequate for the areas where transects were required; therefore, new benchmarks were established with the assistance of DPIW specifically for this project in October 2004 and July 2005. Benchmarks were established above high water mark in view of transects, and positions and heights derived using real time differential GPS, based on existing geodetic GDA control marks. The accuracy of the new benchmarks was verified by reoccupying them using different base stations. It was found that the accuracy of the observed positions relative to the control point was 1 cm in the horizontal and 2 cm in the vertical. The observed ellipsoidal heights were converted to the Australian Height Datum (AHD) 1983 using the geoid model Ausgeoid '98 which is the current standard in Australia. The AUS Geoid model was checked by occupying several AHD benchmarks on both sides of the Tamar Estuary. These newly established benchmarks were described to assist in their relocation for future monitoring.

2.3 Surveying of the intertidal zone

The mud surface along the transects was surveyed between December and March of 2004 and 2005 from high tide mark to the low-tide extent of *S. anglica* using a Topcon GTS-603 Total Station (Figure 2.2). Surface elevation was recorded approximately every three metres or where there was a visible change in surface elevation. A thin metal plate was place on the marsh surface beneath the survey pole and reflector to prevent the pole from sinking in to the mud. Floristic information such as presence/absence of species were recorded along the transect as well as information on the substrate.

2.3.1 Temporal change in marsh cross sectional profiles

Profile data from marshes at Swan Bay, Windermere and Rosevears which were surveyed by A. Pringle and G. Waldschmied between 1972 and 1989 were obtained from the Port of Launceston Pty. Ltd., and reproduced using Adobe Illustrator 10 and adjusted to the Australian Height datam 1983. Cross sectional profiles surveyed between 2004 and 2006 at these locations were overlayed to assess morphological, elevational and *Spartina* cover changes over the past seventeen years.

Figure 2.2: Surveying Marsh surface at Rosevears (W07).

2.3.2 Interpretation of survey data

Point data (longitude, latitude and elevation) were downloaded from the Total Station into Civilcad v6.41, where an alignment was created (for further information on the procedure contact the author). A second alignment with identical longitude and latitude values was created and pre-*Spartina* surface elevation data were manually entered. Digital terrain models (DTMs) for both the surface and basement alignments were then created from which cross sections and longsections could be extracted, allowing a profile of the marsh surface and the assumed pre-*Spartina* surface between HWM and LWM to be obtained.

3 Benchmark Location Information

This section details descriptions and site maps of each Transect site, benchmarks and backsights, to aid in the relocation of these sites. Complete coordinates and elevation data for these sites are listed in table 3.1. Where possible, existing State Permanent Marks (SPMs) were used as backsights. Descriptions and co-ordinate information for SPMs can be found at http://surcom.dpiw.tas.gov.au/surcom/jsp/index.jsp.

When selecting sites for benchmarks, there is a fine balance between finding a position or landmarks that it stable, relatively relocatable but not too conspicuous. Many of the points occur in road reserves subject to regular slashing and road maintenance, or within the coastal reserve adjacent to private allotments. Therefore since installation several benchmarks have been tampered with or lost through road realignment, resealing and by other means. At some locations transects were not surveyed, due the removal or loss of backsights or stations. Drawings for these locations have been included all the same, so that transects can be established at a later time.

Table 3.1: List of all coordinates used throughout the study area.

Point Id	GDA '94 Easting	GDA '94 Northing	AHD '83 Ortho. Hgt.	Posn. Qlty	Sd. Height
74 NOB DRV 1	505886.2657	5423753.096	4.7201	0.0075	0.014
74 NOB DRV 2	505851.6582	5423666.244	5.7141	0.0072	0.0153
74 NOB DRV 3	505777.4114	5423842.813	1.7057	0.0083	0.0084
74 NOB POST	505780.4054	5423827.502	3.3681	0.4429	0.643
DILSTON CONC	506455.0928	5423871.439	1.6457	0.0053	0.0082
DILSTON CONC SH	506461.6102	5423872.5	1.6974	0.0041	0.006
DILSTON POST	506501.669	5423867.996	7.2175	0.0054	0.0077
DILSTON SPIKE	506823.0812	5423306.848	1.6649	0.0047	0.0061
DILSTON STUMP	506857.3673	5423321.956	11.7796	0.0072	0.0092
E04	501,931.98	5426,280.57	1.362	-	0.022
E05	500,168.01	5426,146.06	1.374	-	0.013
E06SPIKE	498,257.33	5426,928.97	1.005	-	0.012
E07	498,603.02	5428,380.03	1.87	-	0.021
E08	499,867.76	5429,497.81	2.504	-	0.023
E1005	497912.3691	5434957.389	5.1474	0.0052	0.0139
E1005A	497462.6632	5434796.471	1.038	0.0049	0.0134
E1005B	497451.4235	5434676.173	1.027	0.0055	0.0152
E1105	496389.4349	5435420.151	1.9716	0.38	0.7811
E1105A	496251.4442	5435391.714	0.7864	0.0083	0.0154
E1105B	496532.9823	5435227.024	0.8854	0.0057	0.0127
GRAVELLY B	497776.58	5428555.18	2.312	-	0.02
JETTY RD	505556.8556	5424580.079	3.4964	0.0081	0.0132
LONE PINE 1	502071.5382	5423374.8	3.3566	0.0074	0.0126
LONE PINE 2	502114.2784	5423229.36	2.6534	0.0144	0.0204
LONE PINE 3	502110.7048	5423230.899	2.8512	0.0146	0.0245
POLE 3	500785.5718	5424649.668	4.9905	0.01	0.0133
POST	501734.6861	5423496.764	6.202	0.0096	0.0385

Table 3.1 Cont: List of all coordinates used throughout the study area

Point Id	GDA '94 Easting	GDA '94 Northing	AHD '83 Ortho. Hgt.	Posn. Qlty	Sd. Height
RIDGE ROAD 1	503225.9674	5422723.87	1.5748	0.0059	0.0148
ROSTELLA 1	504854.2651	5424398.954	1.4455	0.007	0.0122
ROSTELLA 2	504854.2574	5424399.016	1.4444	0.0126	0.0218
ROSTELLA STUMP	504879.2731	5424462.241	8.3901	0.0084	0.0141
SPM9850	498074.580	5429231.518	2.125	-	-
SPM9851	497906.431	5428702.292	2.448	-	-
SPM9853	497590.956	5427504.687	3.088	-	-
SPM10477	505351.714	5423421.120	7.491	-	-
SPM10481	502504.061	5422771.418	3.507	-	-
SPM10482	498144.256	5429866.922	7.997	-	-
SPM10663	500317.130	5426078.407	1.694	-	-
SPM10664	499988.684	5426141.970	3.083	-	-
SPM10665	498182.085	5434135.767	2.384	-	-
SPM10666	498057.007	5434217.036	2.593	-	-
SPM10667	497470.622	5434746.824	1.389	-	-
SPM10672	491631.599	5438184.596	1.9	-	-
SPM10739	500415.220	5425571.621	2.495	-	-
SUPPLY BR	495463.8422	5432647.883	5.4284	0.0036	0.0066
SV DEVILS ELBOW	491,419.51	5439,191.16	1.98	-	0.018
SWAN BAY SEAT	499386.478	5429184.195	2.3951	0.005	0.0119
SWAN PT SIGN	497,785.43	5433,137.19	2.339	-	0.052
TANNER DRV 1	504846.6816	5423321.318	9.426	0.0074	0.0152
W02ALT	503858.0586	5422921.554	1.5168	0.0164	0.0298
W0305	502551.3291	5422670.065	2.3024	0.0085	0.0177
W0405	501776.3972	5423543.934	1.7955	0.0115	0.0428
W0505	500734.7593	5424895.868	7.1625	0.0112	0.0156
W06	499,949.03	5425,402.43	6.679	-	0.02
W0705	499217.154	5425594.797	4.4548	0.006	0.0096
W0705A	499120.1764	5425640.691	5.5223	0.0075	0.012
W08	497,840.09	5426,506.53	1.175	-	0.019
W09	497,493.69	5427,706.95	6.706	-	0.01
W11	497,427.73	5428,545.58	5.032	-	0.019
W12	498,209.32	5430,149.43	1.666	-	0.016
W12BKS	498,178.05	5430,172.12	5.341	-	1.299
W13	497,312.34	5431,760.37	2.489	-	0.011
W13BKS	497,298.47	5431,811.18	3.708	-	0.014
W14	497,538.56	5433,004.14	2.957	-	0.015
W1505	495995.7309	5432252.552	1.4993	0.0116	0.0304
W1605	494905.957	5433589.331	6.4628	0.0076	0.0161
W1605A	494847.7072	5433714.012	8.3706	0.0075	0.015
W1605T	494905.8419	5433588.66	6.041	0.2303	0.4796
W1705	494066.5508	5435744.756	5.978	0.0148	0.0271
W1705A	493953.1484	5435812.978	8.4586	0.006	0.0108
W1705B	493985.5393	5435795.254	6.8761	0.011	0.0195

Table 3.2: Benchmark information for transect W01

74 NOB DRV 1 (W01 – Legana)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	505886.2657	5423753.096	* see notes
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	4.7201	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Metal spike in ground with pink flagging.			
Locality	In foreshore reserve near north-west property boundary, 74 Nobelius Drive, Legana.			
Sight access	Two wheel drive vehicle access to 74 Nobelius Drive, then by foot. Land access permission required from Landholder.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
	505851.6582	5423666.244	5.7141	221.2905	93.49
Description	On the north-western side of the property there is a walk way to the foreshore reserve, bound by a row of trees on northwest and a fence on the south-east. The backsight is located at one of the fence star pickets on the south-east of the walkway, approx. halfway, and is indicated by pink flagging.			
Note	The transect is offset from the STN. Refer to bearings and distances on Figure 3.1 to determine the alignment.			

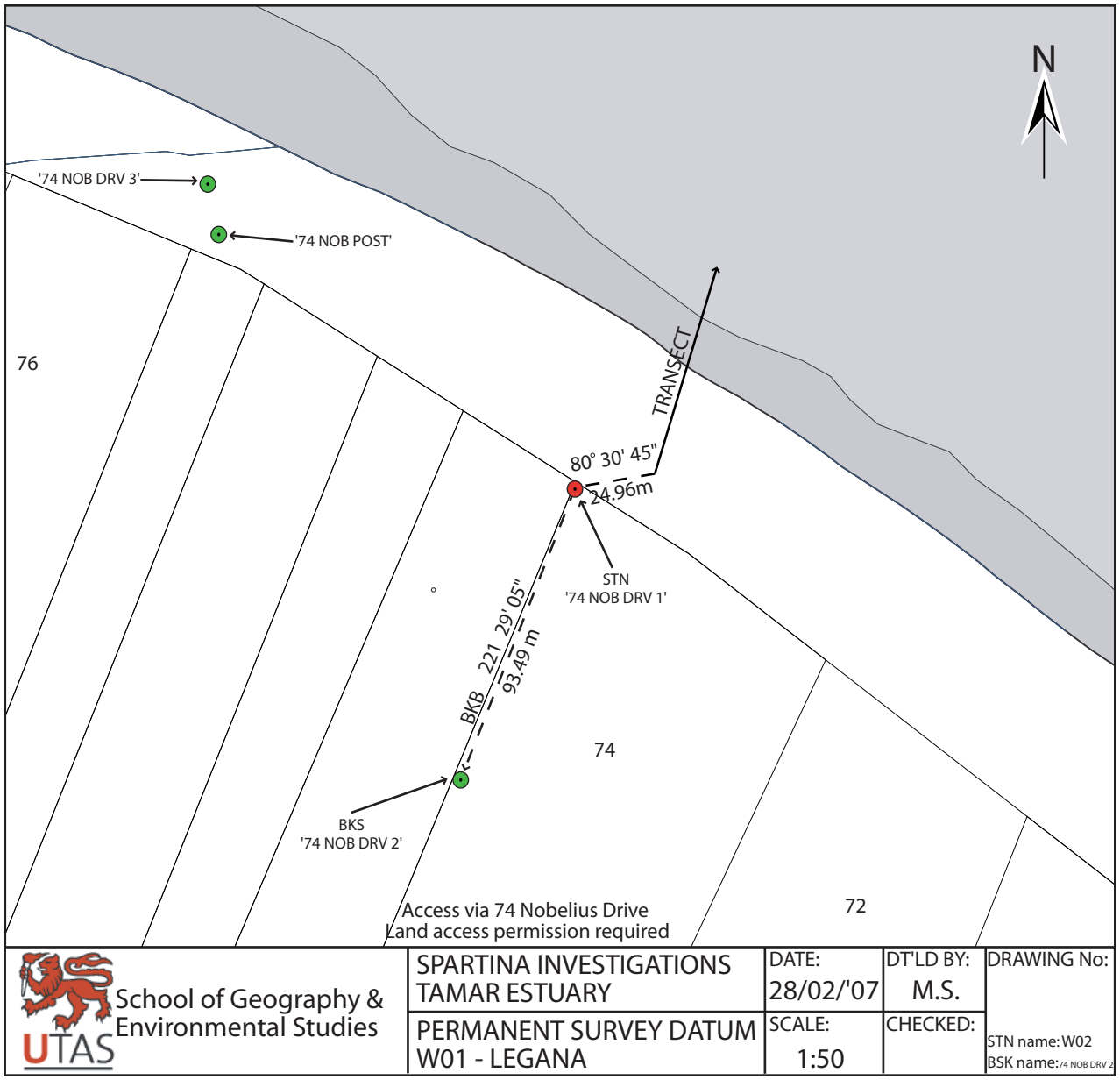


Figure 3.1: Transect W01, Legana.

Table 3.3: Benchmark information for transect E01

DILSTON CONC SH (E01 – Dilston)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	506461.6102	5423872.5	* see notes
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.6974	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Roofing nail in the centre of large concrete platform			
Locality	On concrete platform in the foreshore reserve in front of "Tarcoola", 1291 East Tamar Hwy, Dilston			
Sight access	Walk in from "Tarcoola". Land property access required.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
DILSTON CONC	506455.0928	5423871.439	1.6457	260.4510	6.603	See Fig 3.2 & 3.3
DILSTON POST	506501.669	5423867.996	7.2175	96.3400	40.329	See Fig 3.4
Note	The transect is offset from the STN. Refer to bearings and distances on Figure 3.5 to determine the alignment.					

Figure 3.2: Photo taken from DILSTON POST looking toward other benchmarks.

Figure 3.3: DILSTON CONC, the main backsight, is on the corner of the concrete slab. DILSTON CONC SH is located in the centre of the slab and is the Station for the transect. The Transect is to the right of the photograph.

Figure 3.4: DILSTON POST was used as a secondary backsight and is in the centre of a large concrete boundary post

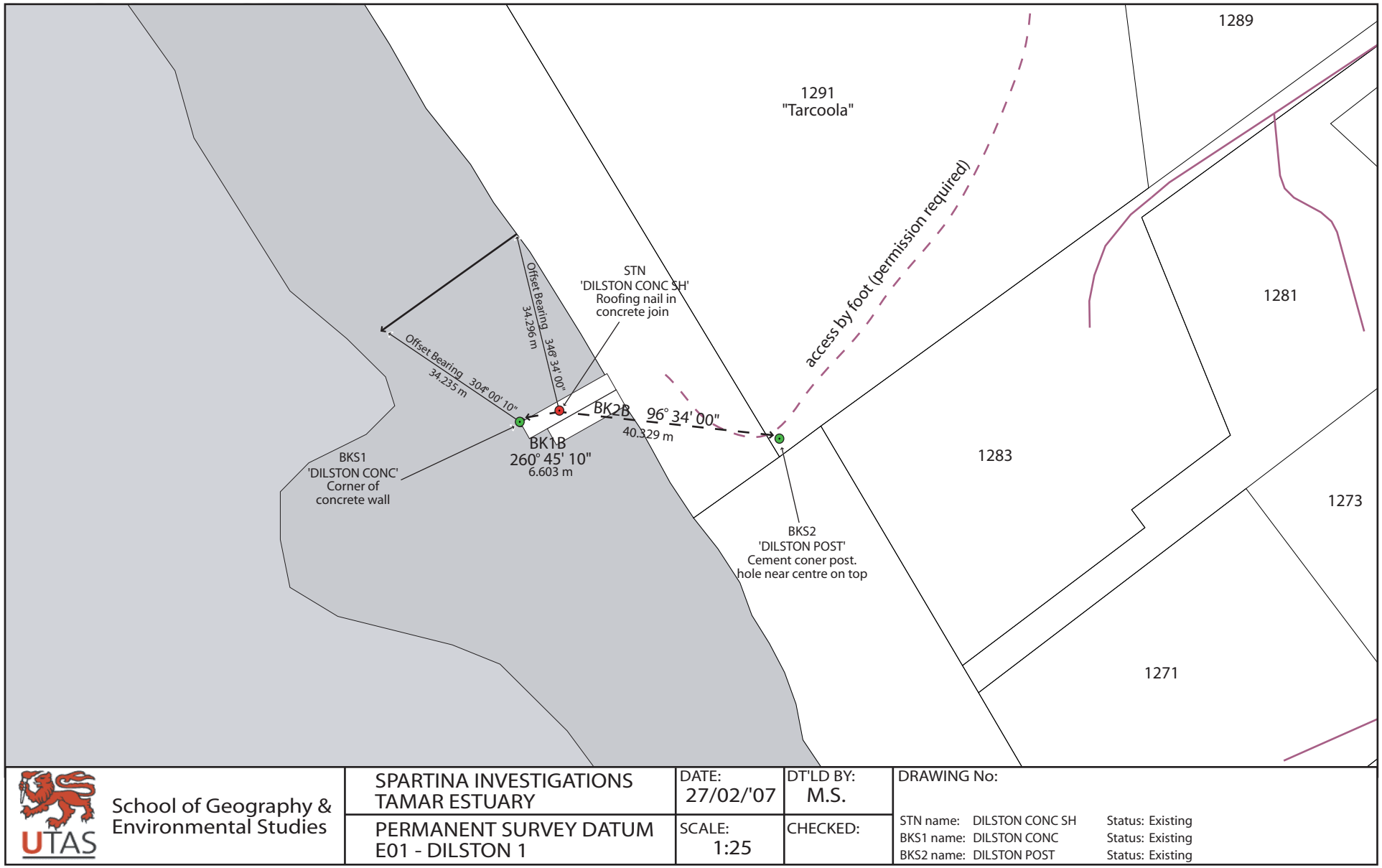


Figure 3.5: Transect E01, Dilston.

Table 3.4: Benchmark information for transect W02

W02 (W02 – Legana 2)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	503858.0586	5422921.554	N/A
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.5168	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Wooden stake in mud surface at HWM pink flagging on stake and on vegetation			
Locality				
Sight access	**Jetty Road access:** Park vehicle at end of road and continue on foot. The foreshore reserve is entered via a white gate where there are signs about land reclamation and fines for dumping rubbish. Go through gate, turn right, and walk over marsh and across creek to opposite bank. Transect is marked by pink flagging on vegetation. The access point requires no land access permission, however the substrate is soft and crossing the creek can be very difficult. **Beach Road access:** This alternative access point is relatively easy however requires land access permission. Walk down to marsh via the vacant block at 80 beach road. The last part of the descent is steep and densely vegetated, but there are clearly defined animal tracks to follow.			

NOTE: NO BACKSIGHTS INSTALLED - Backsight was destroyed and therefore this transect has not been surveyed.

Table 3.5: Benchmark information for transect W02Alt

RIDGE ROAD (W02Alt – Legana 2)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	503225.9674	5422723.87	N/A
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.5748	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Wooden peg on marsh surface at base of cliff			
Locality	Coastal reserve at end of Ridge Road, Legana.			
Sight access	Road reserve at end of Ridge Road as shown in the cadastral, has been sold, therefore property access permission is required. The descent to the marsh is vegetated and very steep with no made track. Accessing the site with survey equipment is therefore difficult.			

Note: No backsight installed. Location not surveyed.

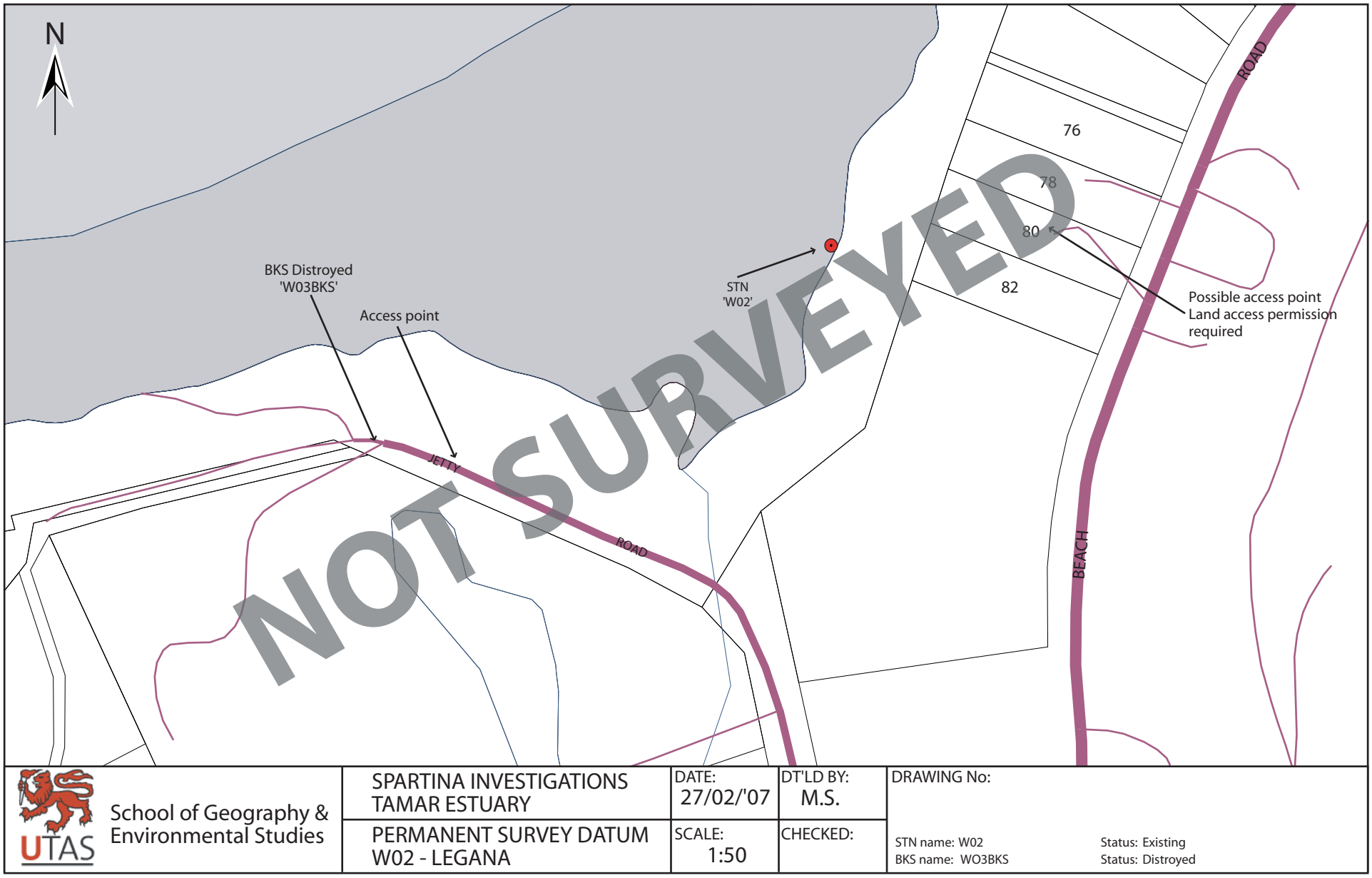


Figure 3.6: Transect W02, Legana.

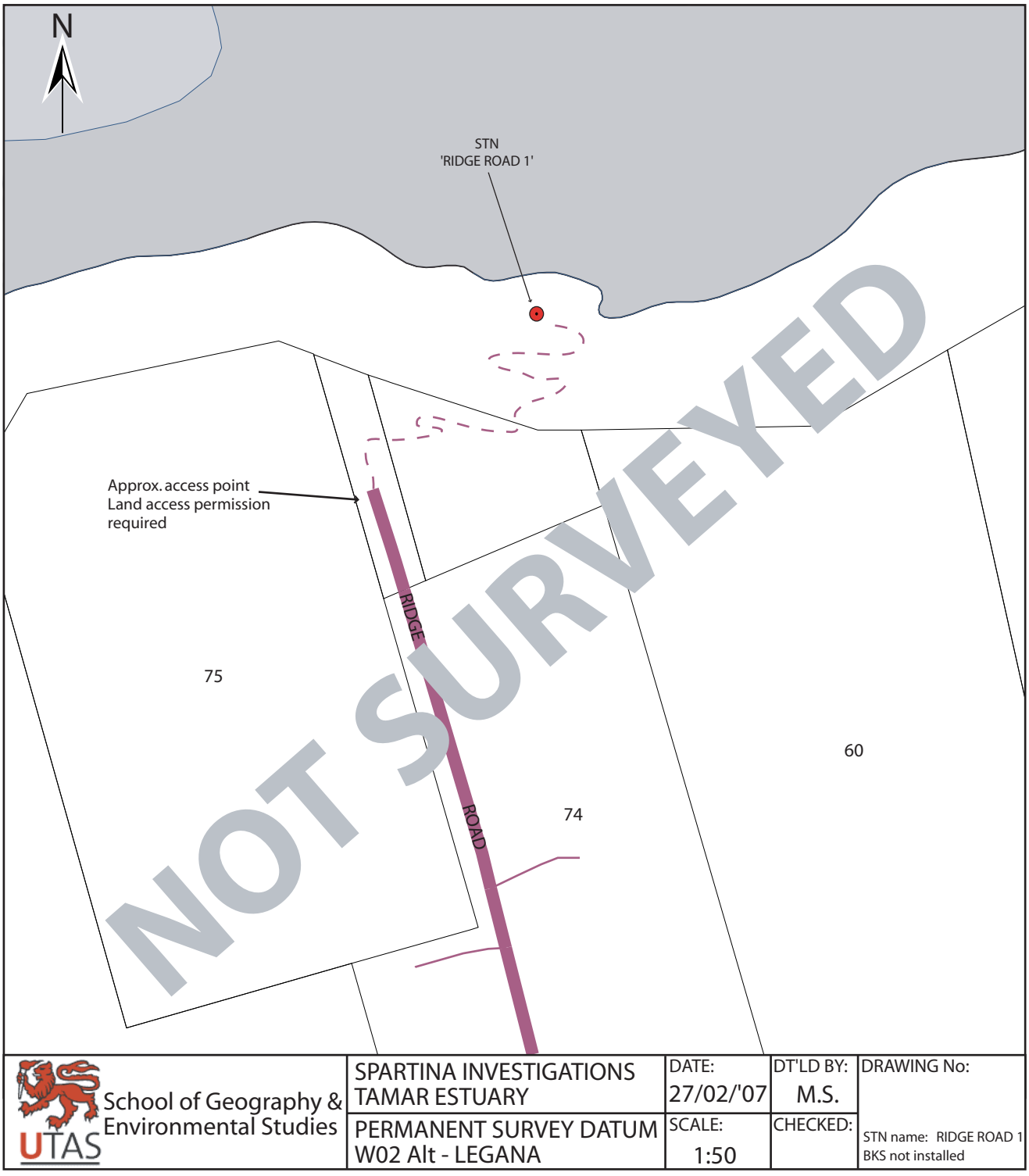


Figure 3.7: Alternative W02 transect, Legana.

Table 3.6: Benchmark information for transect E02

JETTY RD (E02 – Dilston)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	505556.8556	5424580.079			-
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	3.4964	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Wooden Peg with pink flagging tape.					
Locality	End of Jetty Rd, Dilston, near entrance to Dilston nursery.					
Sight access	2WD access.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10477	505351.714	5423421.120	7.491	-	-	*
74 NOB DRV POST	505780.4054	5423827.502	3.3681	-	-	

* Refer to http://surcom.dpiw.tas.gov.au

Table 3.7: Benchmark information for transect E02Alt

ROSTELLA 2 (E02Alt – Dilston)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	504854.2574	5424399.016			-
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	1.4444	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Star picket flush with ground surface					
Locality	On foreshore reserve in front of 101 Rosella Drive, Dilston					
Sight access	Drive into reserve (2WD access) walk through vegetation to marsh, turn right and walk along marsh to edge of vegetation. Go through fence onto foreshore reserve and walk approx 20 m. Benchmark is about 3m from property boundary fence.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10477	505351.714	5423421.120	7.491	-	-	*
TANNER DRV 1	504846.6816	5423321.318	9.426	-	-	

* Refer to http://surcom.dpiw.tas.gov.au

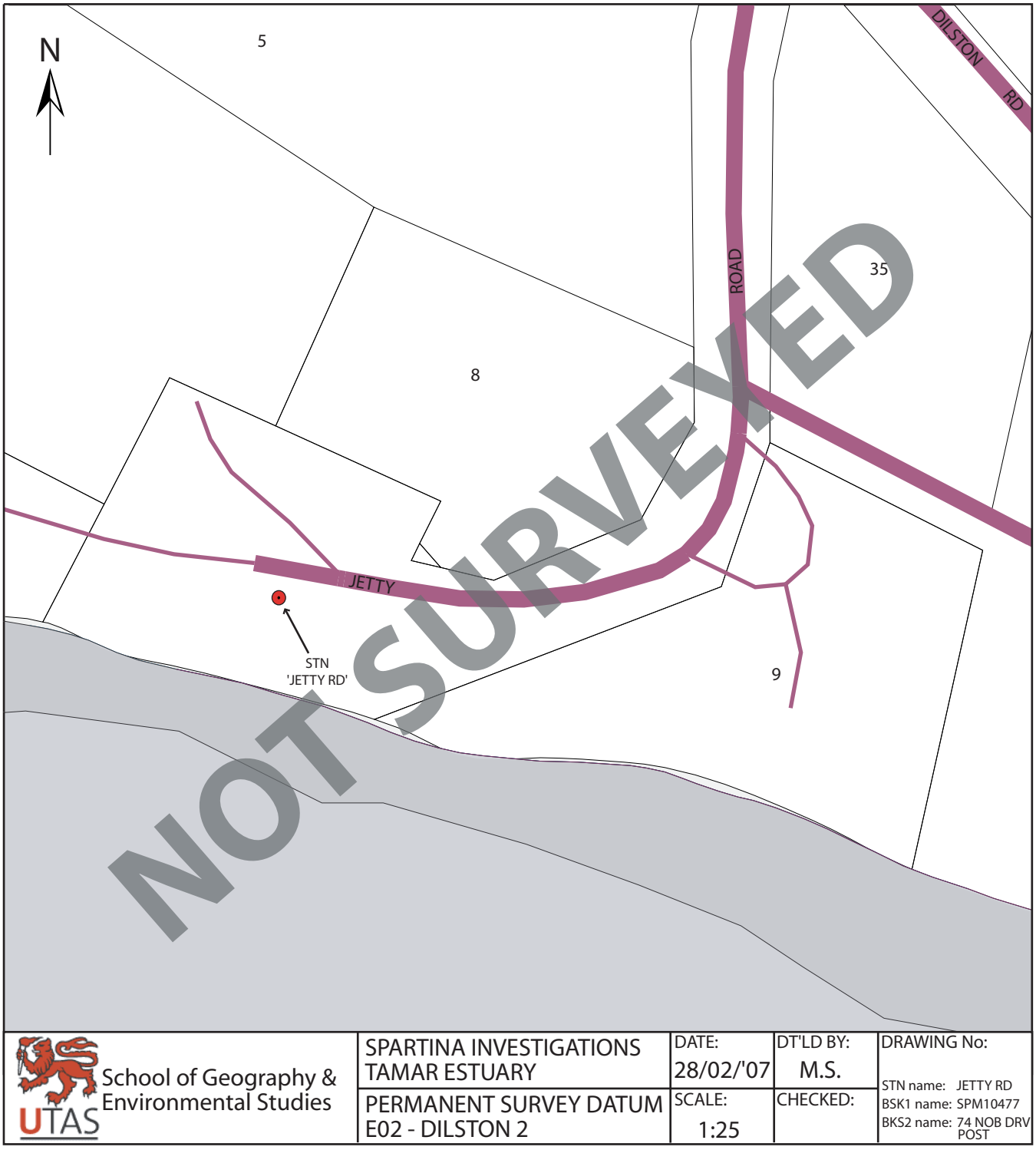


Figure 3.8: Transect E02, Dilston.

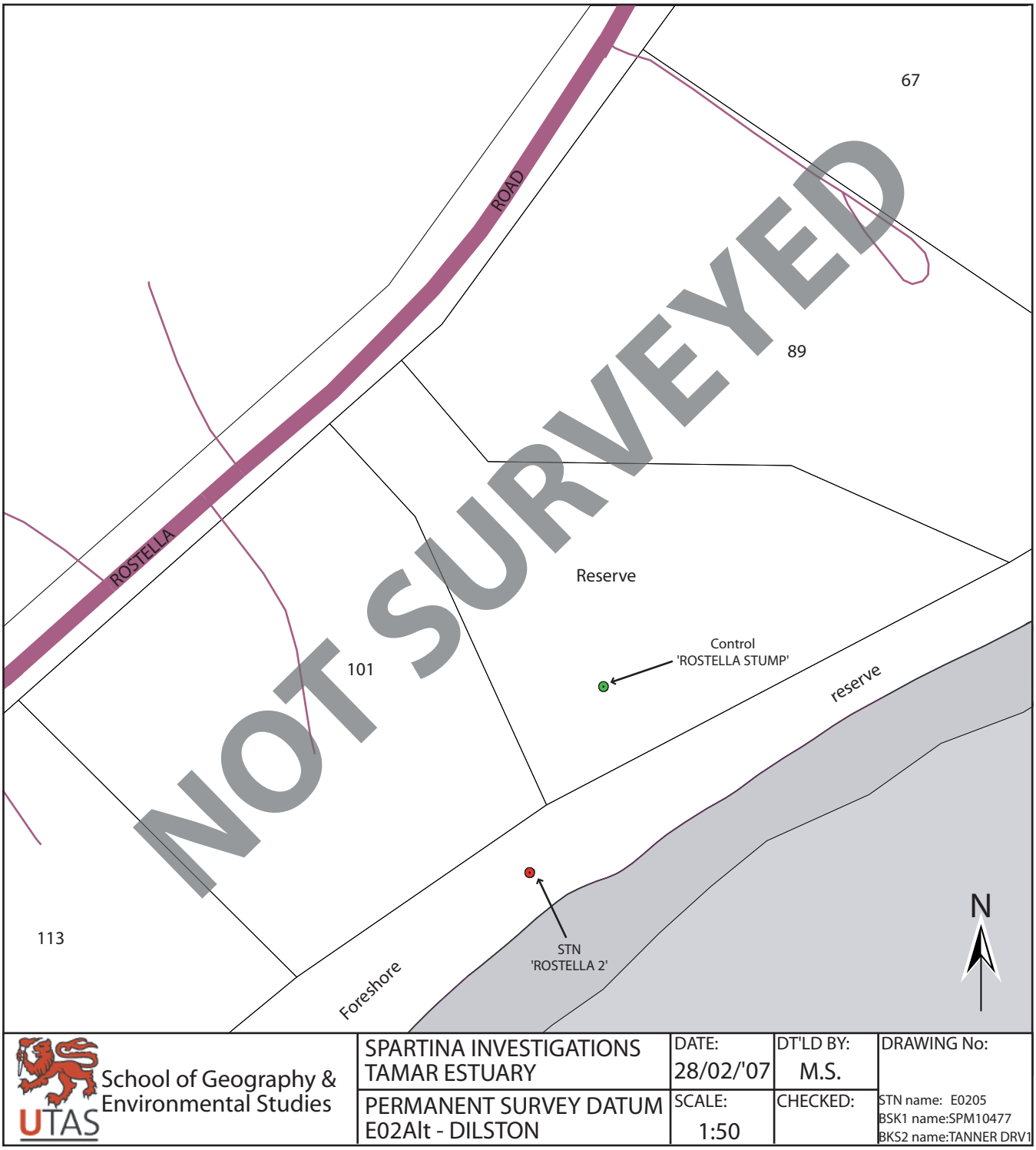


Figure 3.9: Alternative E02 transect, Dilston.

Table 3.8: Benchmark information for transect W03

W0305 (W03 – Loch Lea)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	502551.3291	5422670.065			70.2125
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	2.3024	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Metal spike with pink flagging					
Locality	On eastern side of Rosevears Drive, opposite letterbox of 63, 4.19 meters in from edge of road.					
Sight access	Two wheel drive vehicle access.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM	502504.061	5422771.418	3.507	344.5955	111.87	*

* Refer to http://surcom.dpiw.tas.gov.au

3.10: Location of W03 benchmark.

Figure 3.1: Transect W01, Legana.

Figure 3.11: Transect W03, Loch Lea.

Table 3.9: Benchmark information for transect W04

W0405 (E04 – Rosevears 1)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	501776.3972	5423543.934			45.2100
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	1.7955	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Round concrete plug in PVC pipe with brass screw marking point.					
Locality	Opposite Strathlyn Winery, 14 metres seaward from the 'Tamar Attractions' sign.					
Sight access	Two wheel drive vehicle access.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
POST	501734.6861	5423496.764	6.202	221.2905	63.016	See Fig 3.12c.

Figure 3.12: Transect W04, Rosevears, In front of Strathlyn Winery. **a)** and **b)** show location and distance to STN from sign, and **c)** shows Backsight.

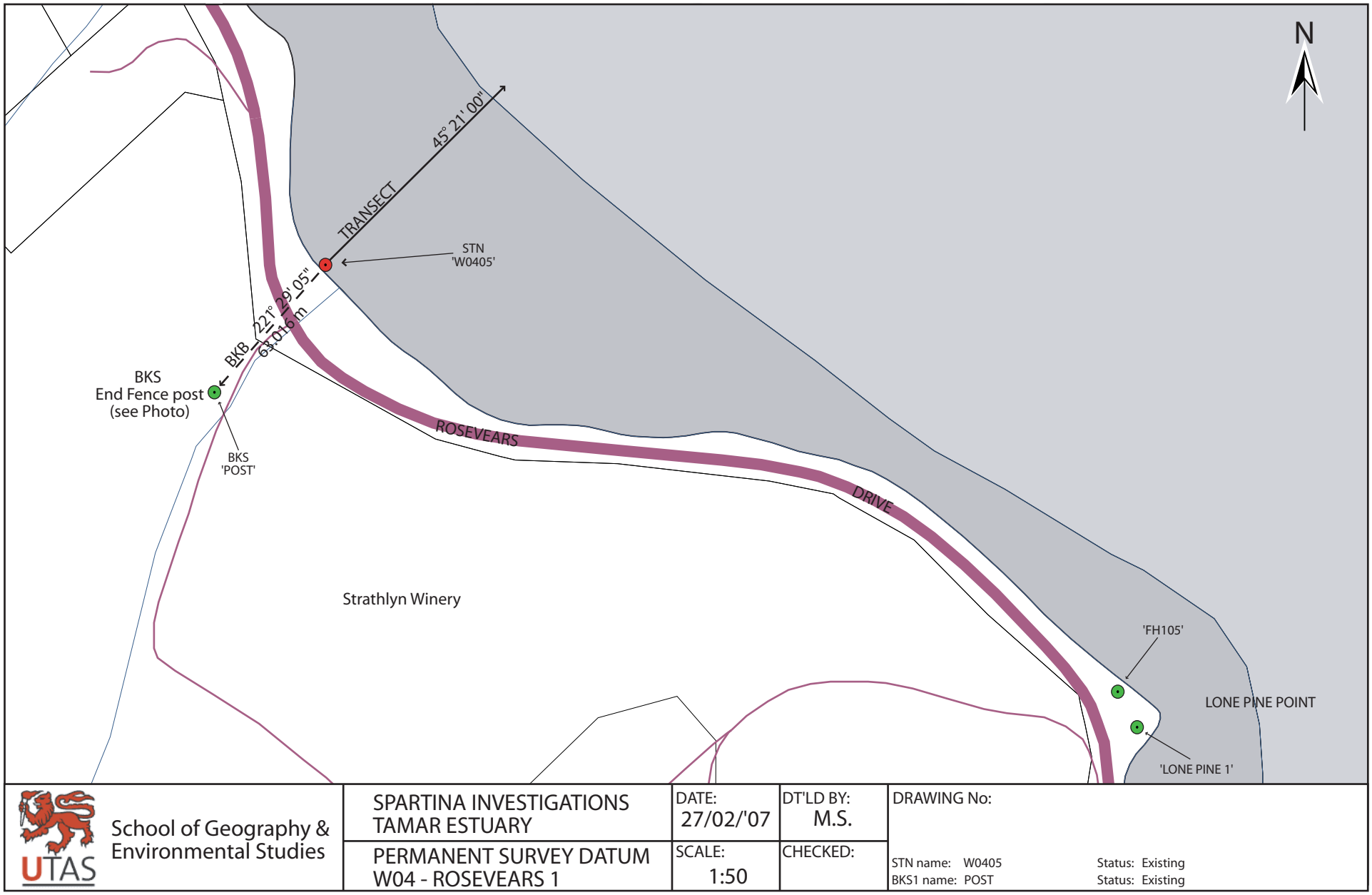


Figure 3.13: Transect W04, Rosevears.

Table 3.10: Benchmark information for transect E04

E04 (E04 – Windermere)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	501931.9822	5426280.574	-
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.3617	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Star picket just above ground surface 1m out from boundary fence of 259 Windermere Road. Marked on fence with orange flagging.			
Locality	Reserve between 259 and 271 Windermere Road			
Sight access	Park beside Windermere road and walk through reserve.			

Table 3.11: Benchmark information for transect W05

W05 (W0505 – Rosevears 2)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	500734.7593	5424895.868	-
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
		Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	STN has not been installed, but two other points have which can be used for its installation with a total station. This will allow for the establishment of a transect in the middle on the embayment from the head of Atkinson's Creek.			
Locality	W0505: Opposite 187 Rosevears Drive, 1 m off road. POLE 3: Opposite 169 Rosevears Drive, 4.5 m meters seaward of power pole no. 3 toward large *Acacia* covered in *Dodder*. Proposed STN site: Directly north west of Atkinson's Creek on embankment above 183 or 184 Rosevears drive, with a clear view of transect for the head of Atkinson Creek to the lower extent of *Spartina.*			
Sight access	Accessible by two wheel drive vehicle			

Backsight Information

	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
W0505	500734.7593	5424895.868	7.163	-	-	Round concrete plug in PVC
POLE 3	500785.5718	5424649.668	4.991	-	-	Metal spike

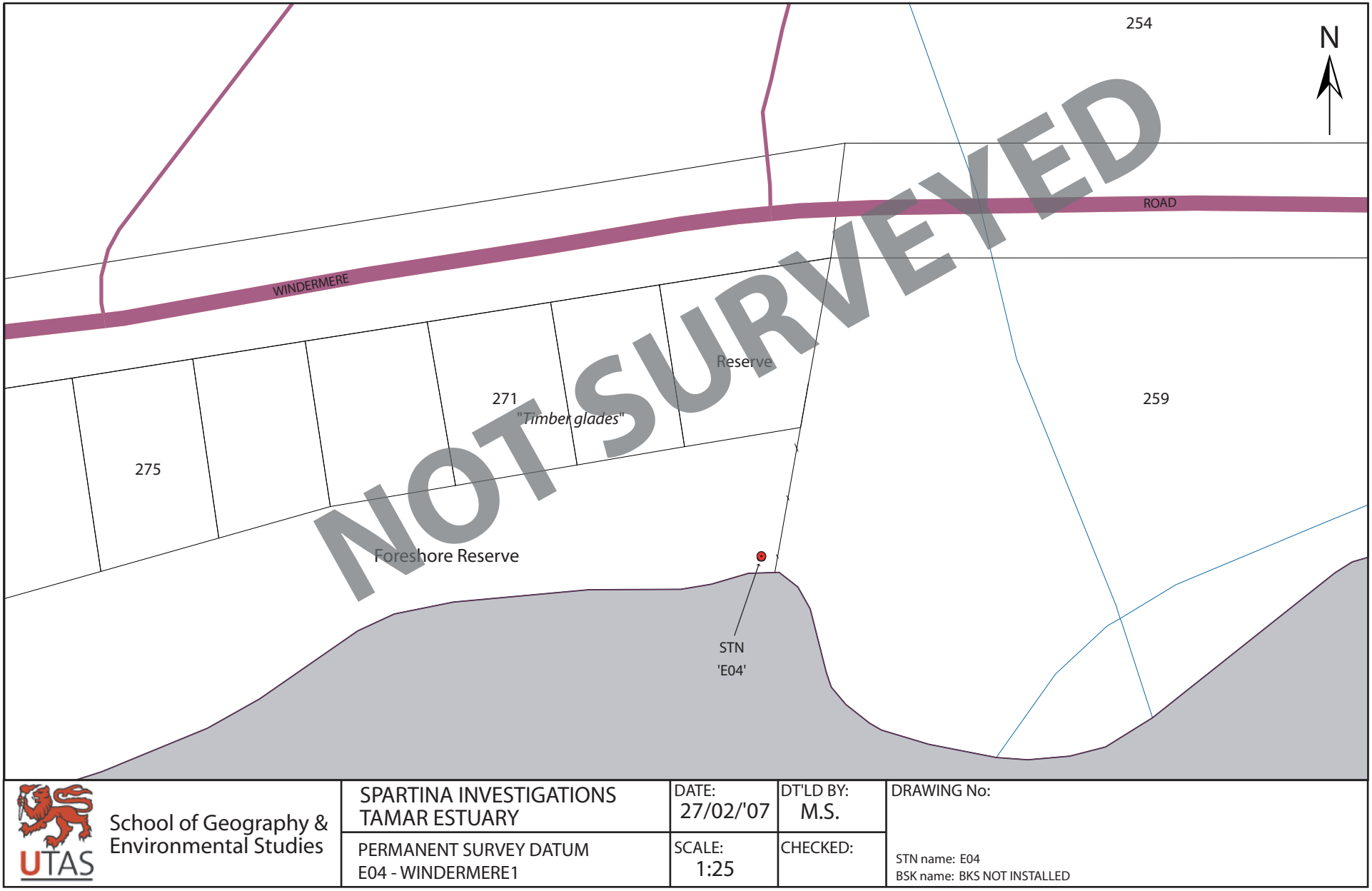


Figure 3.14: Transect E04, Rosevears.

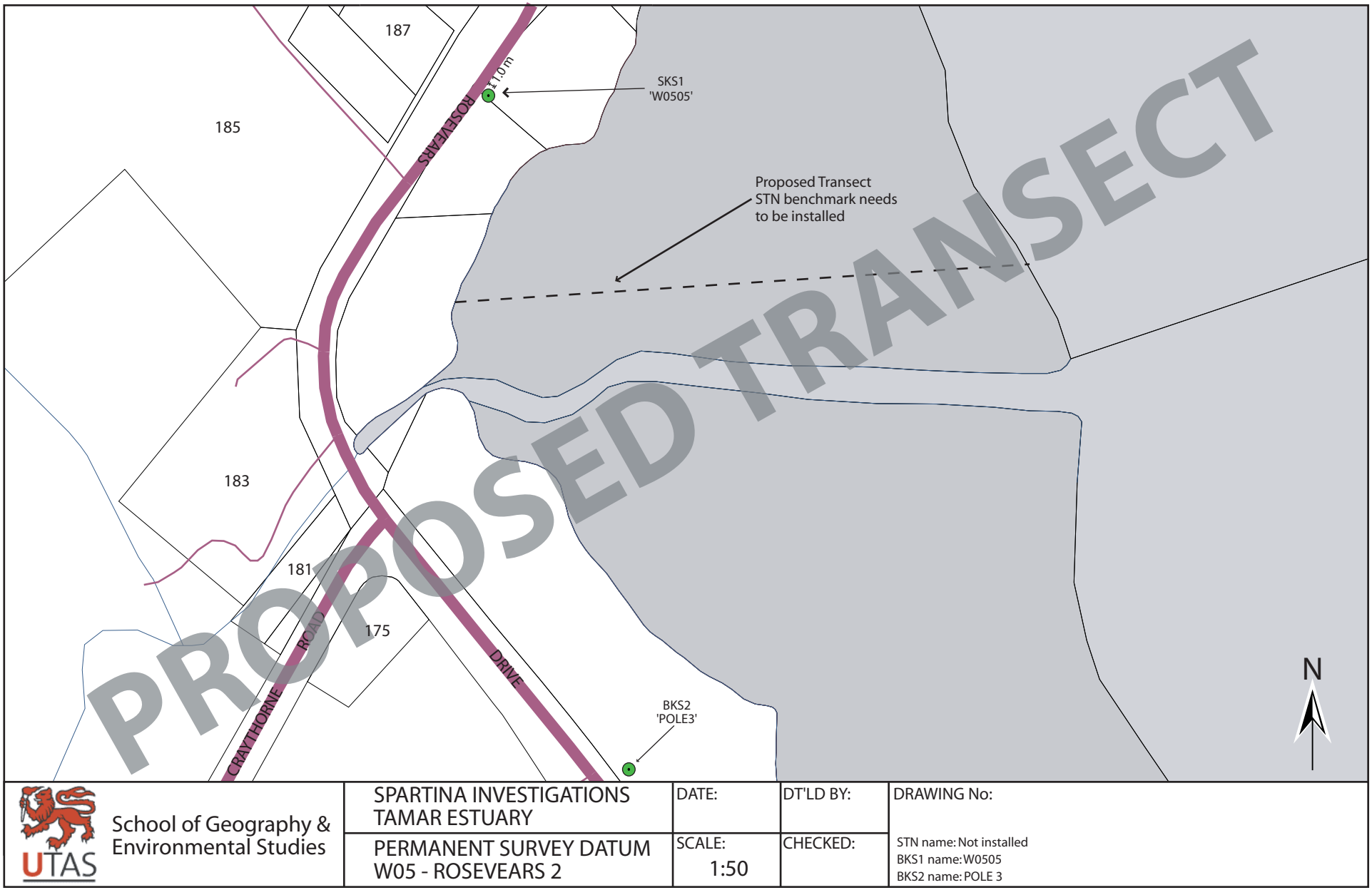


Figure 3.15: Transect W05, Rosevears.

Table 3.12: Benchmark information for transect E05

E05 (E05 – Windermere)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	500168.0111	5426146.055			196.3230
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	1.3741	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Star picket					
Locality	In front yard of 445 Windermere Road, west of clothes line at HW mark (just seaward of a low rock wall.					
Sight access	From Pontoon, walk west along shoreline. Property access is required.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10664	499988.684	5426141.970	3.083	268.4245	179.70	*
W06	502551.3291	5422670.065	16.252	1963230	775.86	See below

Table 3.13: Benchmark information for transect W06

W06 (W06 – Rosevears 3)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	502551.3291	5422670.065			16.2515
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
		Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	Large Brass bolt set in Cement block –old PLA mark					
Locality	In front of fence line between power pole and letter box of 229 Rosevears Drive.					
Sight access	Accessible by two wheel drive vehicle. To set up over STN, letterbox may have to be removed – contact property owner.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10664	499988.684	5426141.970	3.083	3.0405	740.87	*
E05	500168.0111	5426146.055	1.3741	16.2515	775.86	See above

* Refer to http://surcom.dpiw.tas.gov.au

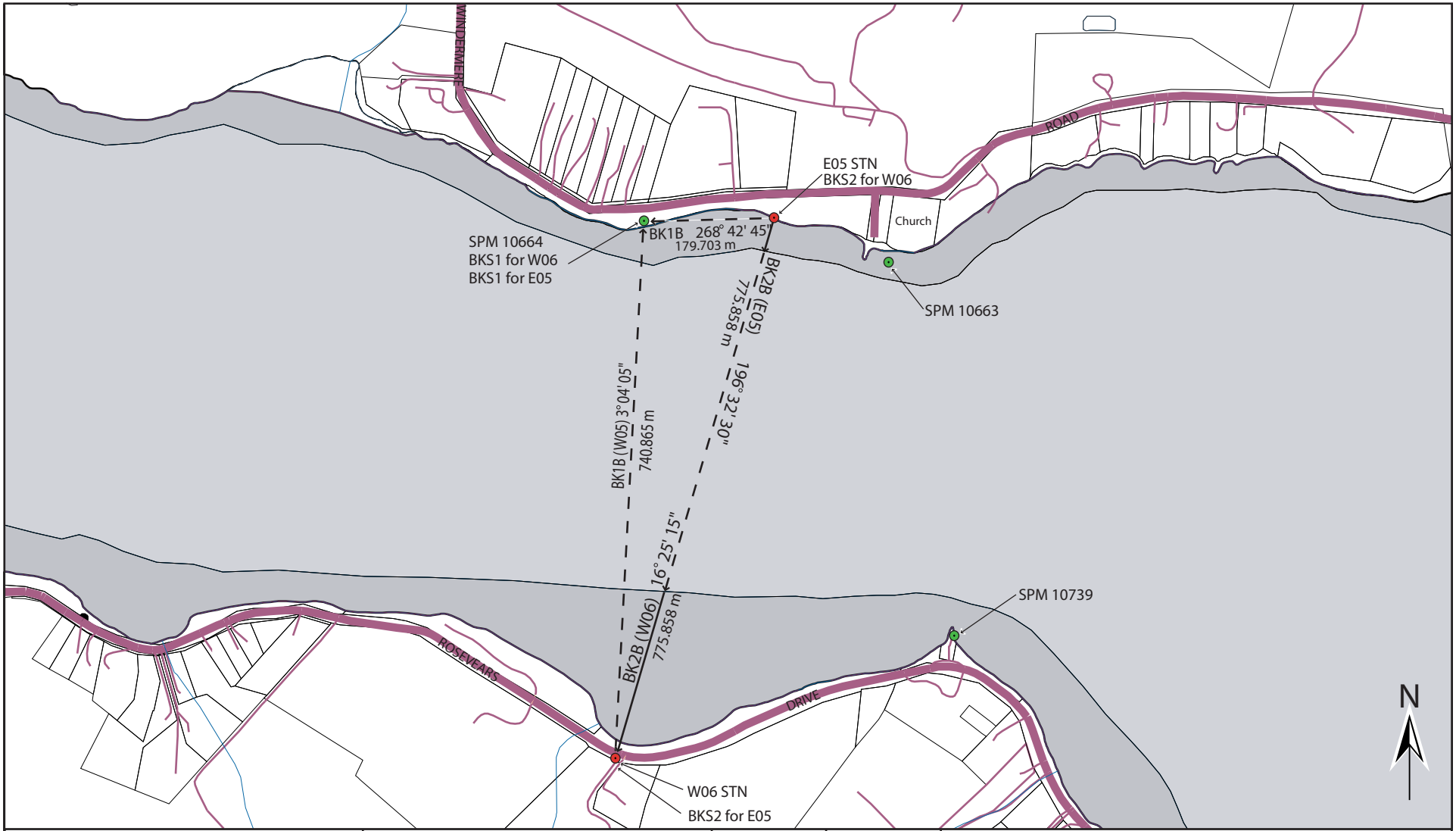


Figure 3.16: Transects E05 and W06, Windermere and Rosevears.

Table 3.14: Benchmark information for transect W07

W0705 (W07 – Rosevears 4)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	499217.1521	5425594.789	31.2405
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	4.4586	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Round concrete plug in PVC Pipe with brass screw.			
Locality	Directly opposite the north-western edge of the driveway of "The Elms", 267 Rosevears Drive, Rosevears, 1.21 m off road.			
Site access	Two wheel drive vehicle access.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
W07A	499120.1764	5425640.691	5.5223	295.1930	107.374
Description	Front south-eastern corner of monument.			

Table 3.15: Benchmark information for transect W08

W08 (W08 – Lanena)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	497840.0883	5426506.532	44.3849
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.1751	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Short star picket protruding 10-20cm from marsh surface at HW.			
Locality	In foreshore reserve, in front of 104 Rosevears Drive. Walk in from 108 Rosevears Drive and cross to neighbouring property near the bottom of the yard. Follow path to jetty. Benchmark is situated on the marsh below and to the south-east of the boatshed.			
Sight access	Via 108 Rosevears Drive. Property access permission required from both 104 and 108 Rosevears Drive.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
E05	498257.3339	5426928.973	1.0046	44.3849	594.011	

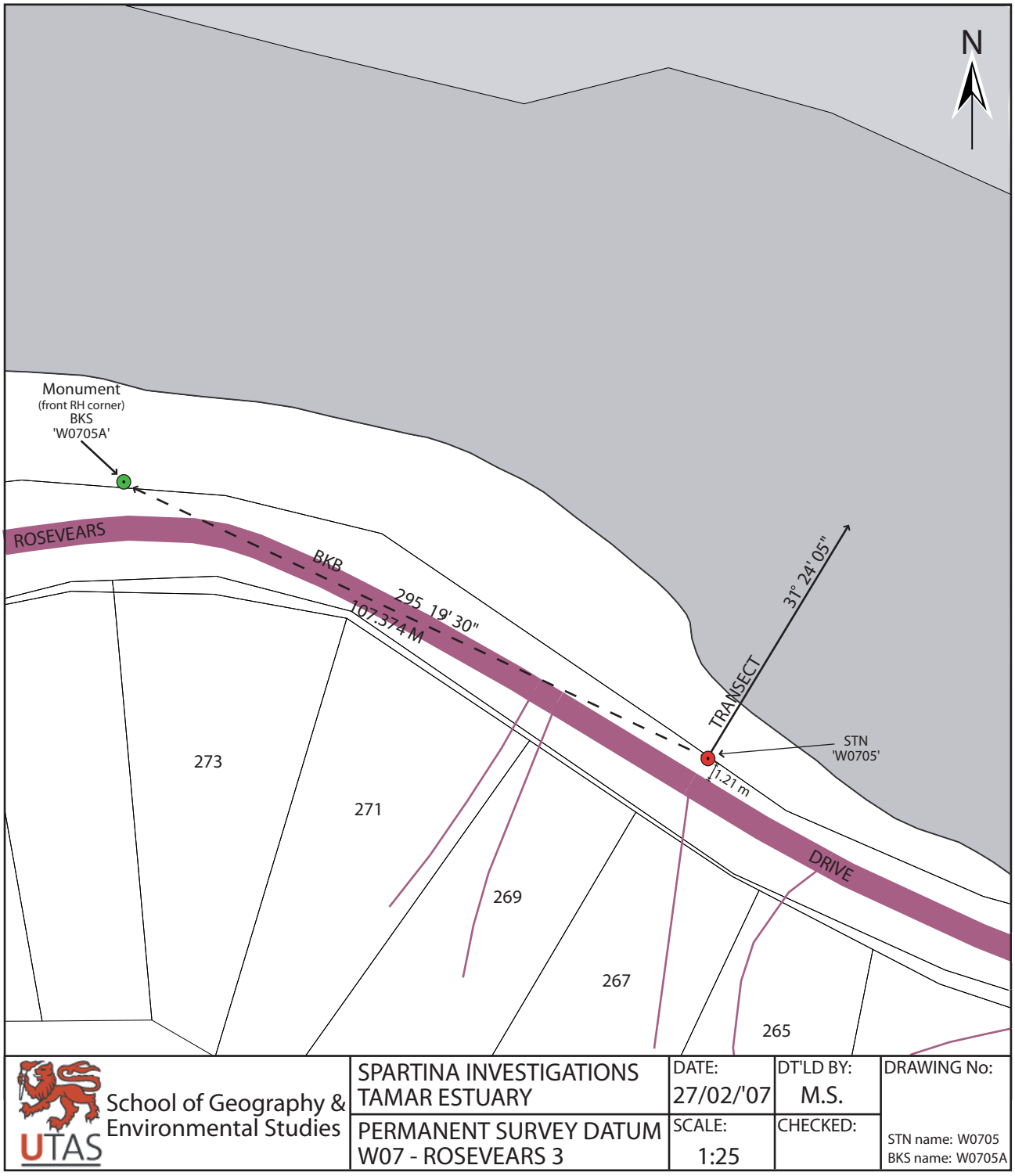


Figure 3.17: Transect W07, Rosevears.

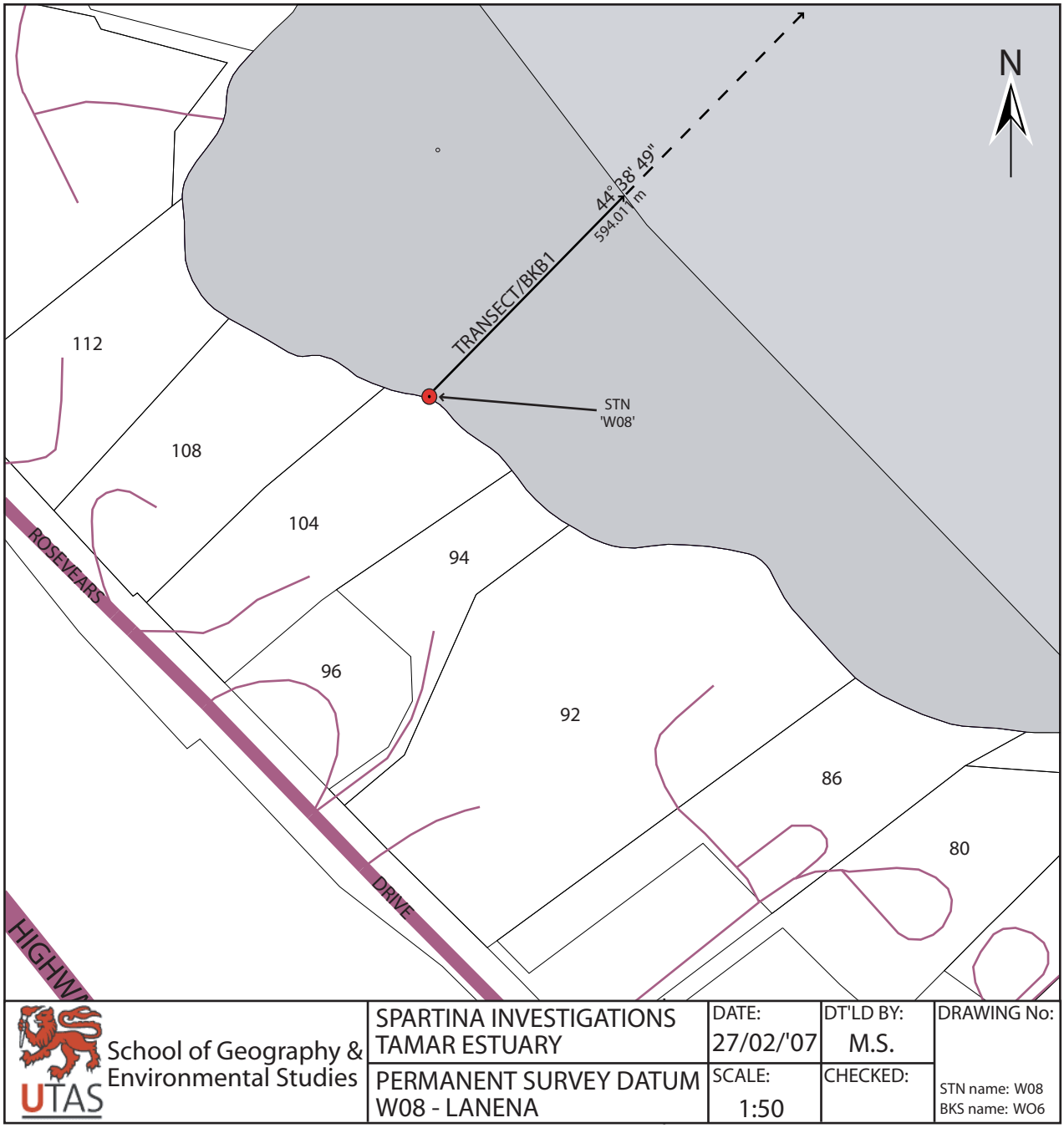


Figure 3.18: Transect W08, Lanena.

Table 3.16: Benchmark information for transect E06

E06SPIKE (E06 – Native Point)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	498257.3339	5426928.973	135.6155
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.0046	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Spike driven into gravel beach with pink flagging on spike and on tree above. Metal detector may be required to locate.			
Locality	Foreshore reserve, native Point Nature Reserve.			
Site access	Drive to Car park in Native Point Reserve and then walk along coast on along walking track.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing** **Dist**
W08	497840.0883	5426506.532	1.1751	135.6155

* Refer to http://surcom.dpiw.tas.gov.au

Table 3.17: Benchmark information for transect W09

W09 (W09 – Blackwall)						
Horizontal Information						
	Zone	**Easting**	**Northing**		**Transect bearing**	
	55	497493.6925	5427706.948		100.4345	
	Datum		**Survey Class**		**Order**	
	Geocentric Datum of Aust 1994		B		Second	
Vertical Information						
	Ht	**Datum**		**Survey Class**	**Order**	
	6.706	Aust Height Datum (Tas) 1983		Satellite - GPS	Third	
Mark Details						
Description	Round concrete plug in PVC Pipe with brass screw.					
Locality	Opposite 125 Gravelly Beach Road, Blackwall. Near power pole.					
Site access	Two wheel drive vehicle access.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	
SPM9853	497590.956	5427504.687	3.088	154.1905	224.558	*

* Refer to http://surcom.dpiw.tas.gov.au

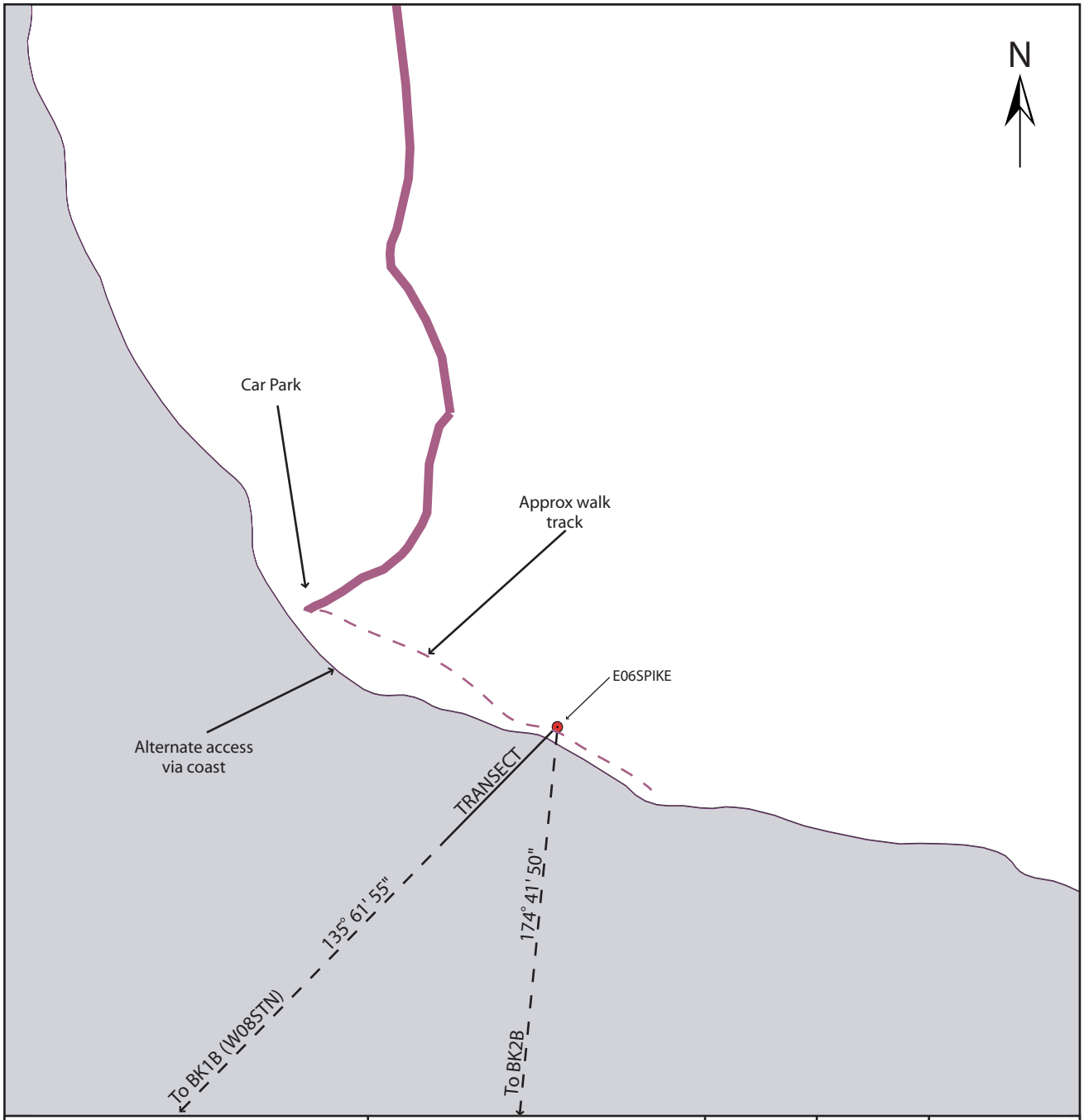


Figure 3.19: Transect E06, Native Point.

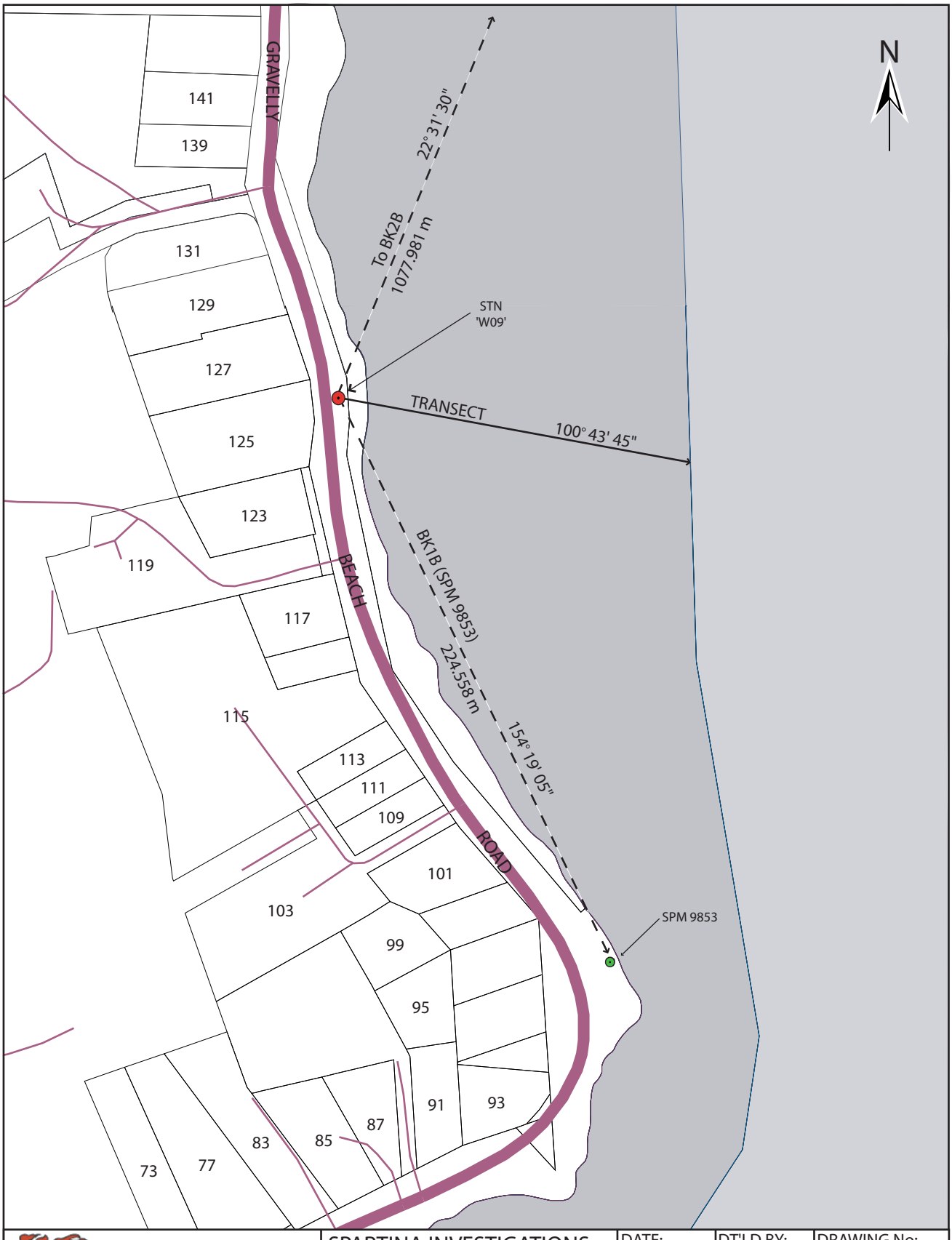


Figure 3.20: Transect W09, Blackwall.

Table 3.18: Benchmark information for transect W10

W11 (W11 – Gravelly Beach)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	497427.7	5428546	-
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	5.0324	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Round concrete plug in PVC pipe with brass screw marking point.			
Locality	Side of Gravelly beach Rd opposite 209 Gravelly Beach Road.			
Site access	2WD vehicle access.			
Backsight Information	**NO BACKSIGHT ESTABLISHED**			
Note	This location has not been surveyed.			

Table 3.19: Benchmark information for transect E07

E07 (E07 – Swan Bay 1)						
Horizontal Information						
	Zone	**Easting**	**Northing**			**Transect bearing**
	55	498603.0155	5428380.027			318.3950
	Datum		**Survey Class**			**Order**
	Geocentric Datum of Aust 1994		B			Second
Vertical Information						
	Ht	**Datum**	**Survey Class**			**Order**
	1.8695	Aust Height Datum (Tas) 1983	Satellite - GPS			Third
Mark Details						
Description	Star Picket level with ground surface approx. 1m in from property boundary fence					
Locality	Foreshore reserve in front of 15 Woodlawn Rd, Swan Bay.					
Site access	2WD access to Woodlawn Rd. Access by foot through 15 Woodlawn Rd (private property, land access permission required).					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM9850	498074.580	5429231.518	2.125	328.1035		+
SPM9851	497906.431	5428702.292	2.448	294.4945		*
Description	+ In old concrete foundation in Recreation Area off Beach Road, Gravelly Beach					
	* On top of seawall, opposite house number 267 Gravelly Beach Road, Gravelly Beach. Refer to http://surcom.dpiw.tas.gov.au					
Note	Land access permission required. Land owner has done extensive clearing of foreshore vegetation, and has moved and electrified fence. Metal detector maybe required to locate point as notes refer to the original fence. flagging has been removed.					

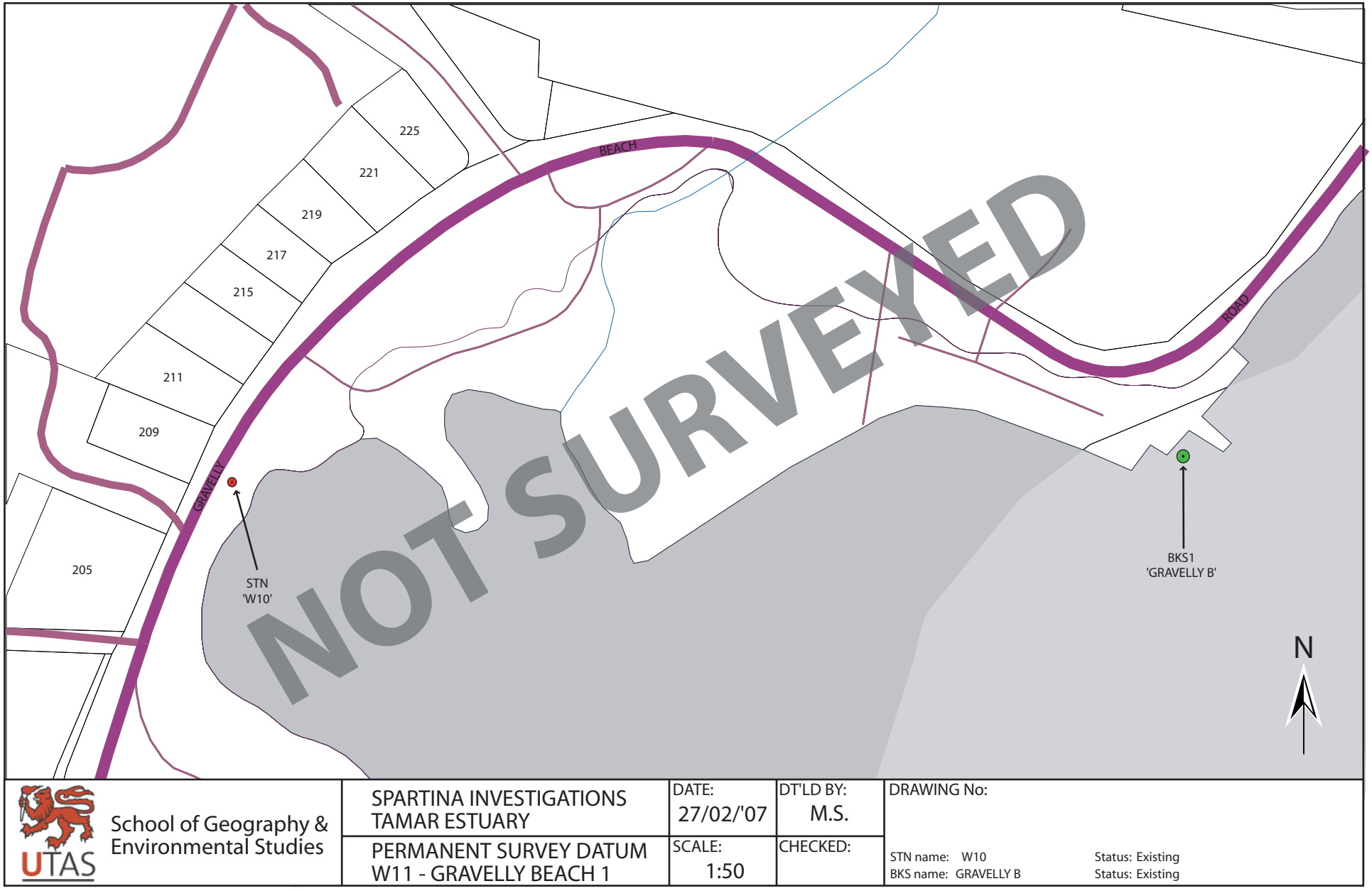


Figure 3.21: Transect W11, Gravelly Beach.

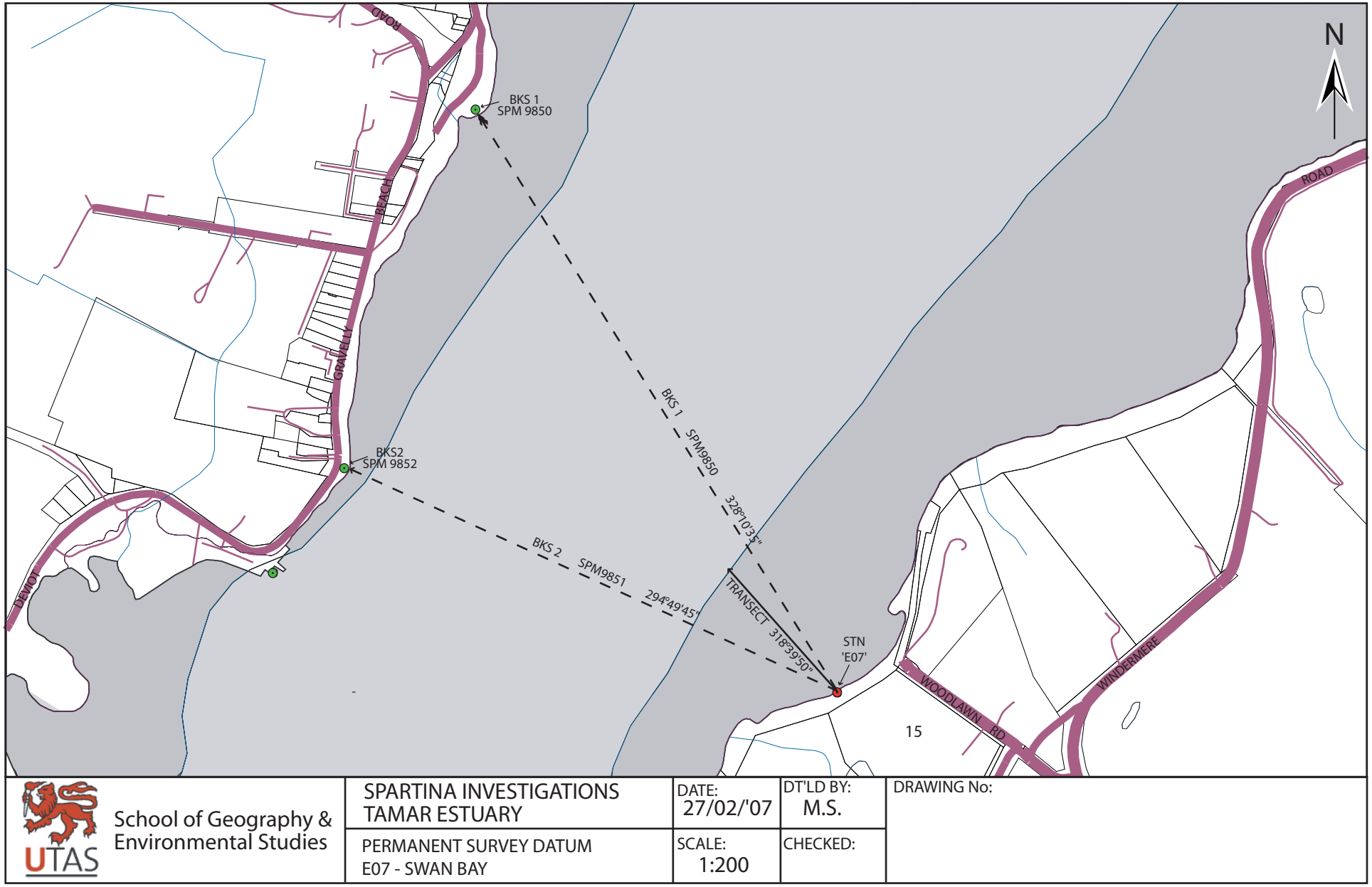


Figure 3.22: Transect E07, Swan Bay.

Table 3.20: Benchmark information for transect E08

E08 (E08 – Swan Bay 2)						
Horizontal Information						
	Zone	**Easting**		**Northing**		**Transect bearing**
	55	499867.6702		5429497.809		322.4740
	Datum			**Survey Class**		**Order**
	Geocentric Datum of Aust 1994			B		Second
Vertical Information						
	Ht	**Datum**			**Survey Class**	**Order**
	2.5037	Aust Height Datum (Tas) 1983			Satellite - GPS	Third
Mark Details						
Description	Position of PLA mark					
Locality	On HW Rock Wall opposite Los Angelos Drive, Swan Bay					
Sight access	2WD Vehicle access. Park under pines opposite Los Angelos drive.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10482	498144.256	5429866.922	7.997	282.0517	1763.307	*
SWAN BAY SEAT	499386.478	5429184.195	2.3951	236.5435	574.702	+
*	Outside No. 53 Beach Rd. G.B. - Refer to http://surcom.dpiw.tas.gov.au.					
+	On front corner of concrete slab, marked with survey paint.					

Table 3.21: Benchmark information for transect W12

W12 (W12 – LITTLE SWAN POINT)						
Horizontal Information						
	Zone	**Easting**		**Northing**		**Transect bearing**
	55	498209.3208		5430149.433		-
	Datum			**Survey Class**		**Order**
	Geocentric Datum of Aust 1994			B		Second
Vertical Information						
	Ht	**Datum**			**Survey Class**	**Order**
	1.6661	Aust Height Datum (Tas) 1983			Satellite - GPS	Third
Mark Details						
Description	Start picket flush with ground surface in clearing approx 1.5m in from high water edge.					
Locality	Foreshore walking track, Little Swan Point					
Sight access	Access on foot via foreshore walking track either from Beach Road or Little Swan Point road.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	
W12BKS	498209.4276	5430149.2	2.0366	-	-	
Description	Star picket protruding between 5 and 10 cm from ground at base of large Eucalypt.					
Note	Storm damage in Feb 2005 resulted in large trees falling over both the STN and backsight, which were not cleared in time for the 2005 field season and therefore surveying was not conducted. Current status of the benchmarks has not been assessed.					

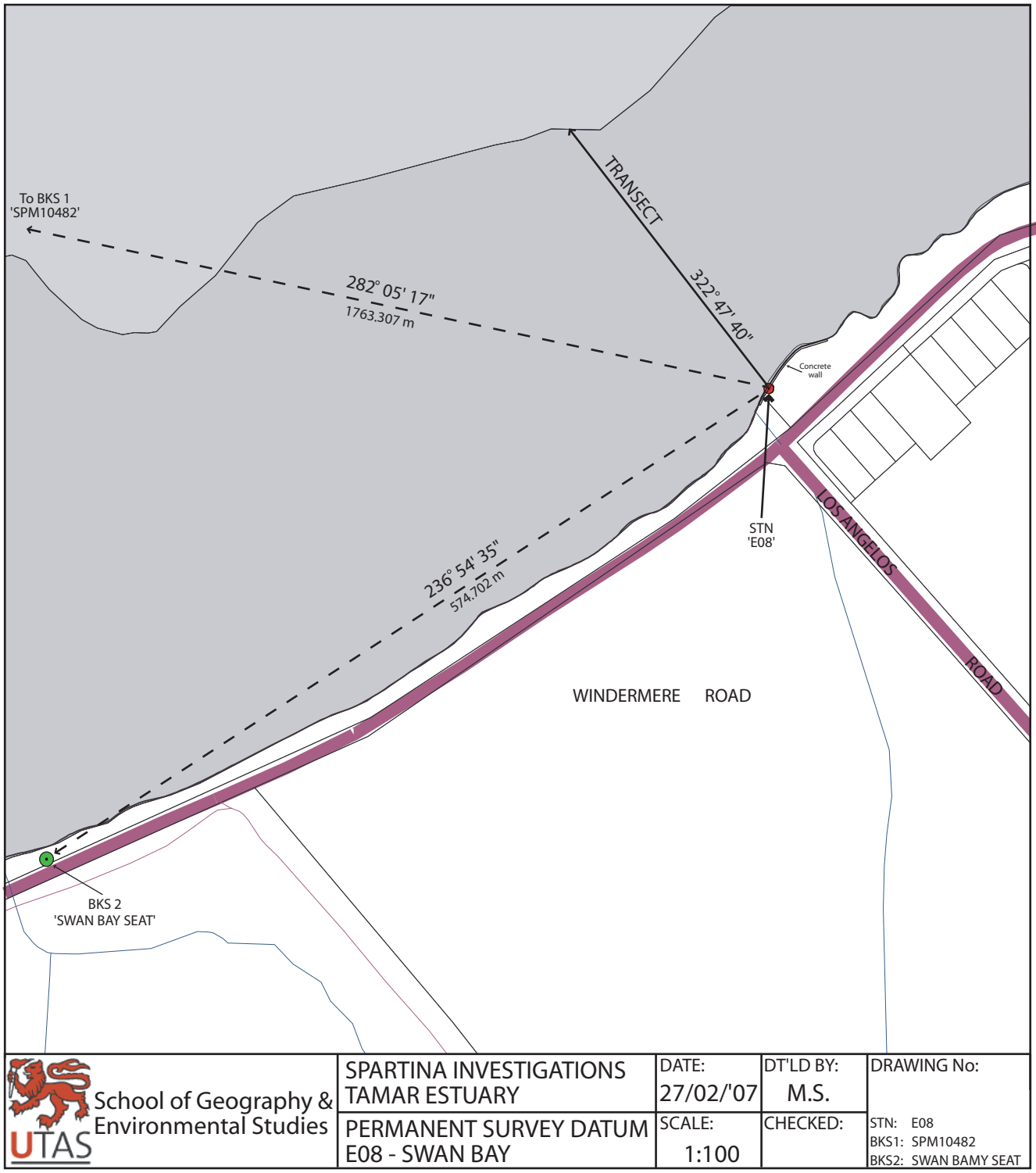


Figure 3.23: Transect E08, Swan Bay.

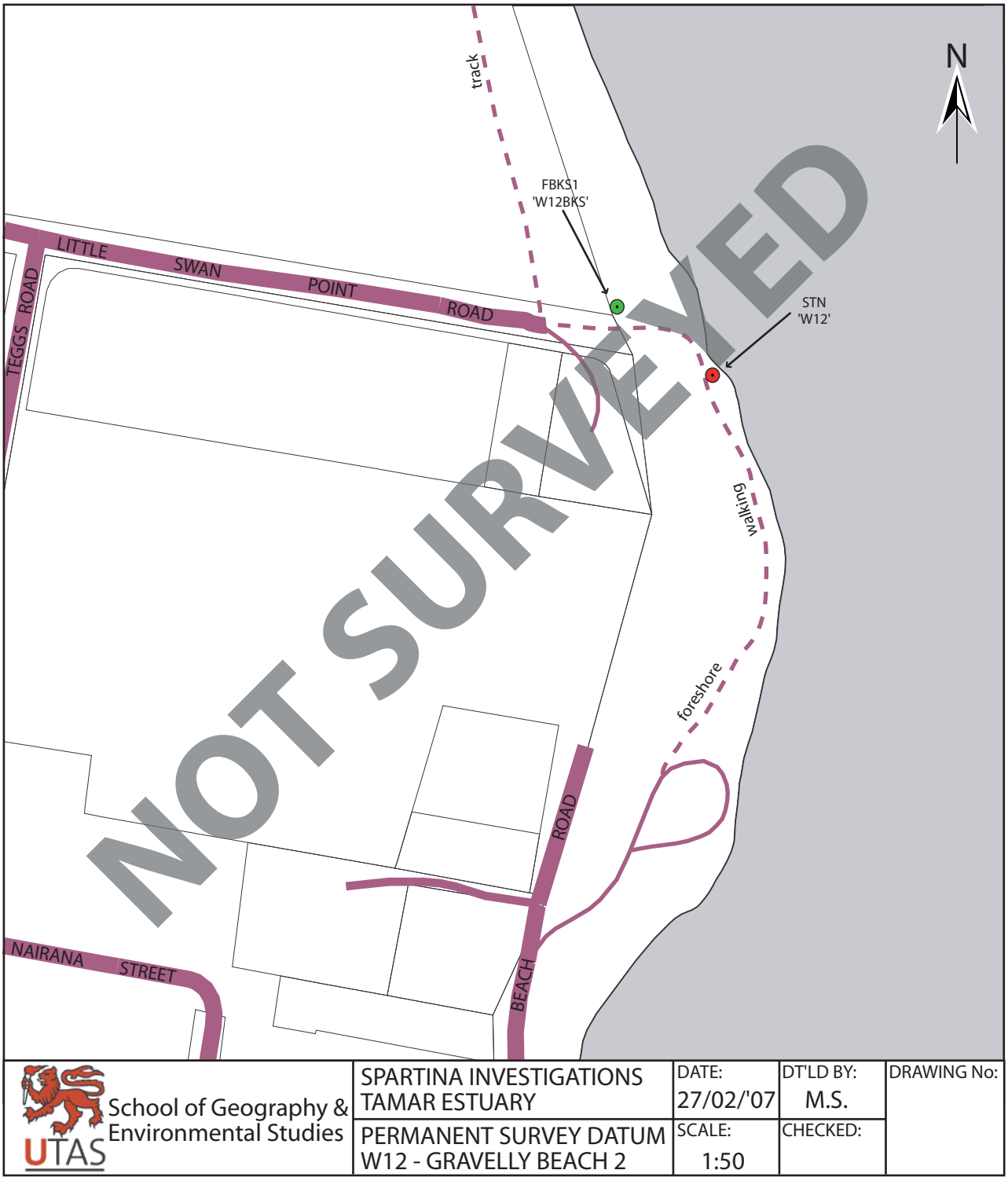


Figure 3.24: Transect W12, Gravelly Beach.

Table 3.22: Benchmark information for transect W14

W14 (W14 – Lightfoot Bay)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	497538.56	5433004.12	-
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	2.9574	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Round concrete plug in PVC pipe with brass screw marking point. Wooden stake beside it marked with orange flagging.			
Locality	Foreshore walking track, Lightfoot Bay.			
Sight access	Closest access is from parking bay at the end of Swan Pt Esplanade. Walk south-west along foreshore walking track towards Supply Bay. Cross over lagoon and continue to top of rise. Benchmark is on the right hand side of the track past vegetation, approx. 1m in from edge of steep high water bank.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
SWAN PT SIGN	497785.4275	5433137.185	2.3388	-	-
Description	White sign at start of Swan Pt walking track.			

NOTE: Due to loss of data, This Transect has only been partially surveyed, and is not included in this report.

Table 3.23: Benchmark information for transect W15

W1505 (W15 – Robigana)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	495995.7309	5432252.552	345.4314
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.4993	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Short Star picket protruding 10-20 cm from marsh surface Seaward of vegetation.			
Locality	Approximately 407 m along foreshore walking track from edge of clearing. Walk through coastal vegetation out to the HW edge of the marsh.			
Sight access	Two wheel drive vehicle access to clearing beside Deviot-Gravelly Beach Road, and then access by foot only.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
SUPPLY BR	495463.8422	5432647.883	5.4284	306.3720	662.997
Description	Bitumen nail and pink flagging in middle of footpath on the Northern side of bridge.			

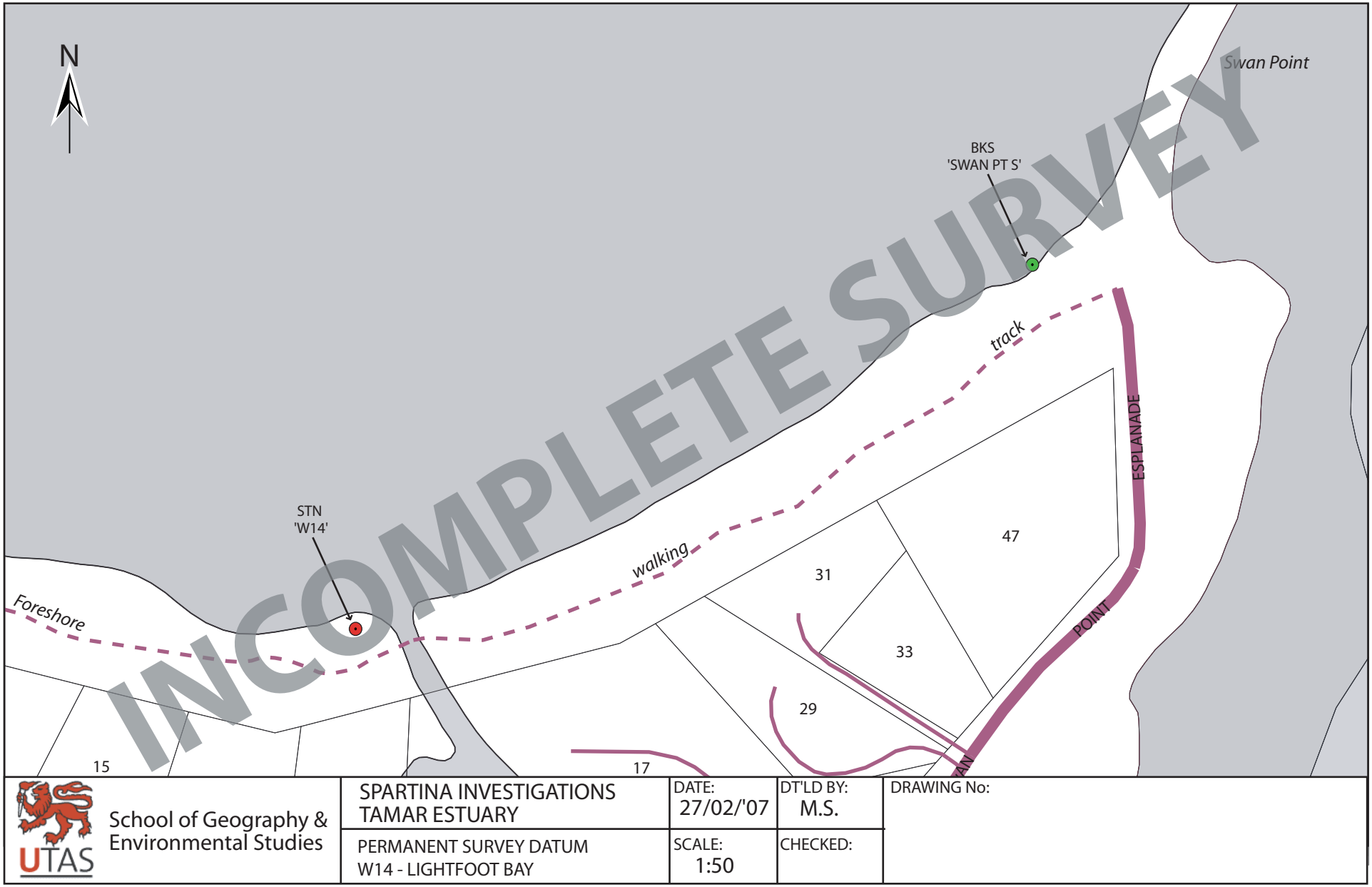


Figure 3.25: Transect W14, Lightfooot Bay.

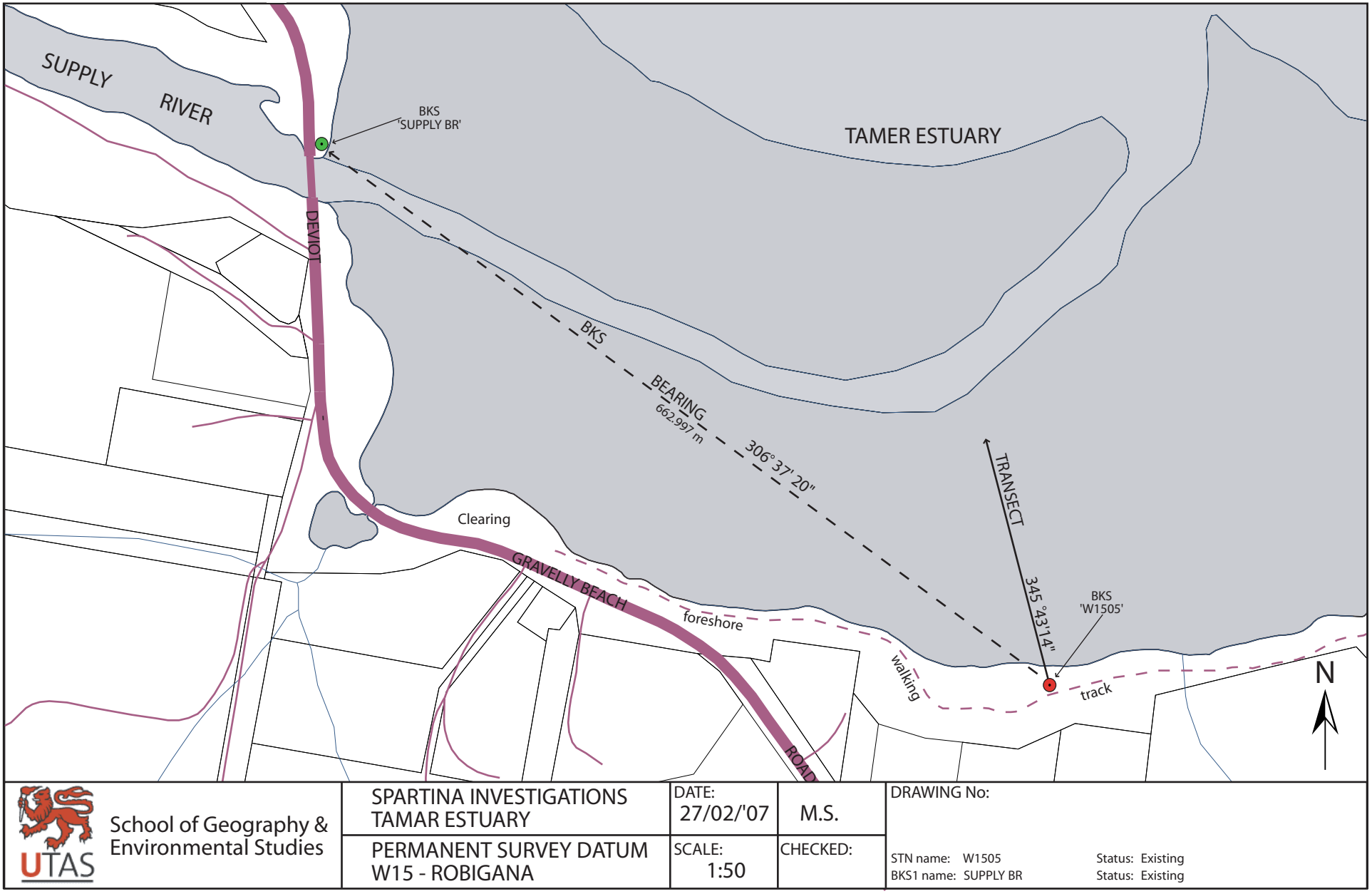


Figure 3.26: Transect W15, Robigana.

Table 3.24: Benchmark information for transect E10

E10 SPIKE (E10 – Hillwood 1)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	497915.374	5434959.198	232.5340
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	5.415	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Spike in edge of road marked with flagging and white arrow on road.			
Locality	Opposite old chapel, Hillwood Jetty Road, Hillwood.			
Sight access	Accessible by two wheel drive vehicle.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
E1005A	497462.6632	5434796.471	1.038	250.1344	481.064
E1005B	497451.4235	5434676.173	1.027	238.3059	543.496
Description	E1005A: Metal spike at HW mark. From track just before boat ramp, walk down a walking track 21 m to Estuary. In front of a big block of bricks.				
	E1005B: no note available.				
Note	There is an SPM at boat ramp. This was not known at time of benchmarking and therefore was not used. USE SPM10667 AS THE PRINCIPAL BACKSIGHT FOR FUTURE SURVEYS.				

Table 3.25: Benchmark information for transect E11

E11 (E11 – Hillwood 2)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	496389.4349*	5435420.151*	-
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	1.9716*	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Star picket protruding 5 - 10 cm from marsh surface at HW mark			
Locality	Johnston's Flat, Craigburn Road, Hillwood.			
Sight access	Marsh access is obtained through coastal vegetation from Craigburn Road approx. 20m before the road turns to gravel (white arrow painted on bitumen indicates access track). Turn right at marsh and walk back toward creek. Marked with flagging.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
E1105A	496251.4442	5435391.714	0.7864	-	-
E1105B	496532.9823	5435227.024	0.8854	-	-
Description	E1105A: Metal spike. 4 m seaward of large boulder				
	E1105B: Metal spike. 11 m seaward if tree with flagging.				

* GPS position quality for this site was poor (0.38) due to dense vegetation. A total station survey should be conducted using one of the backsights as the STN and the other as the backsight, and take a side shot of the STN to determine a more accurate position. This transect has not been surveyed.

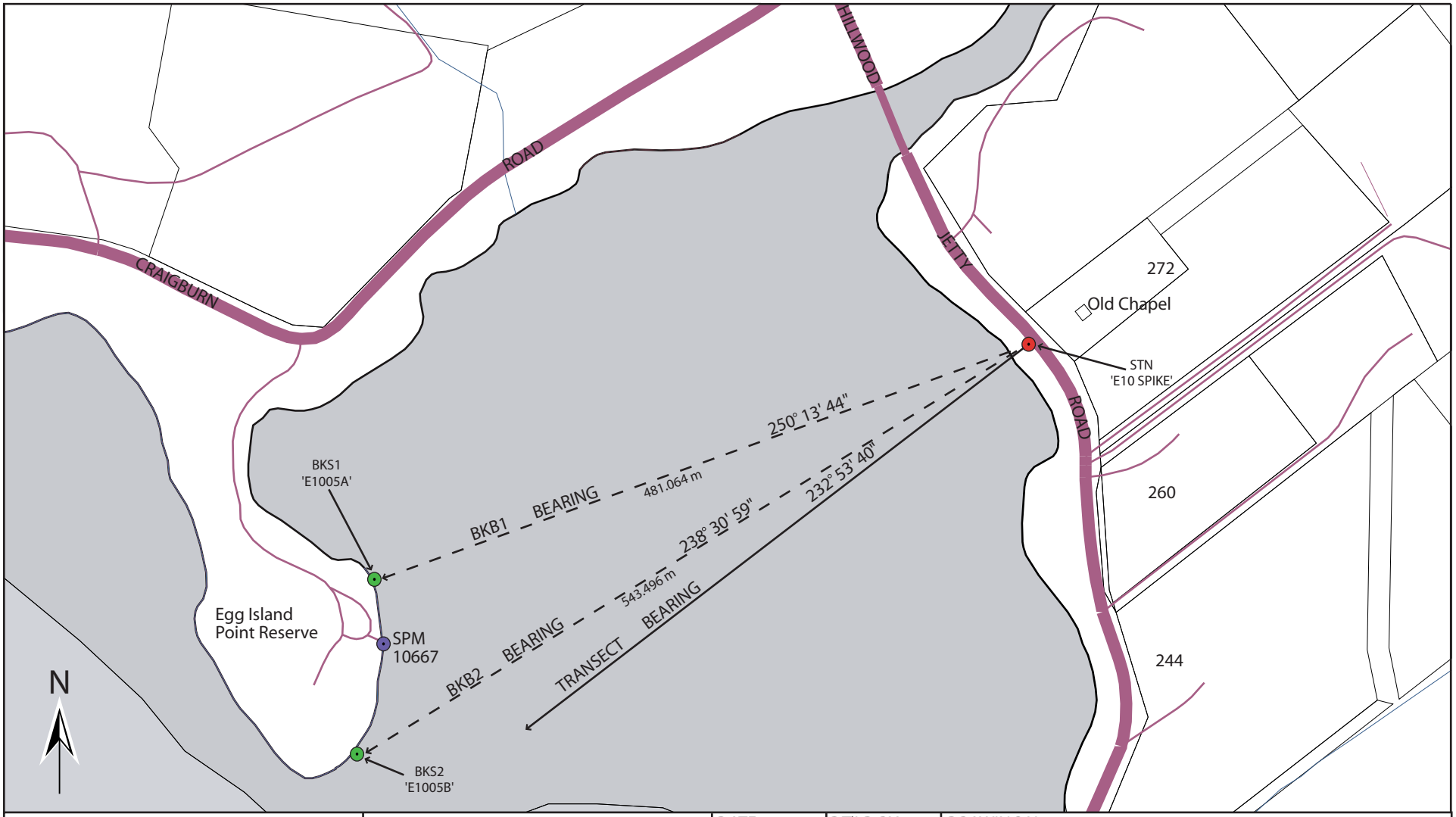


Figure 3.27: Transect E10, Hillwood.

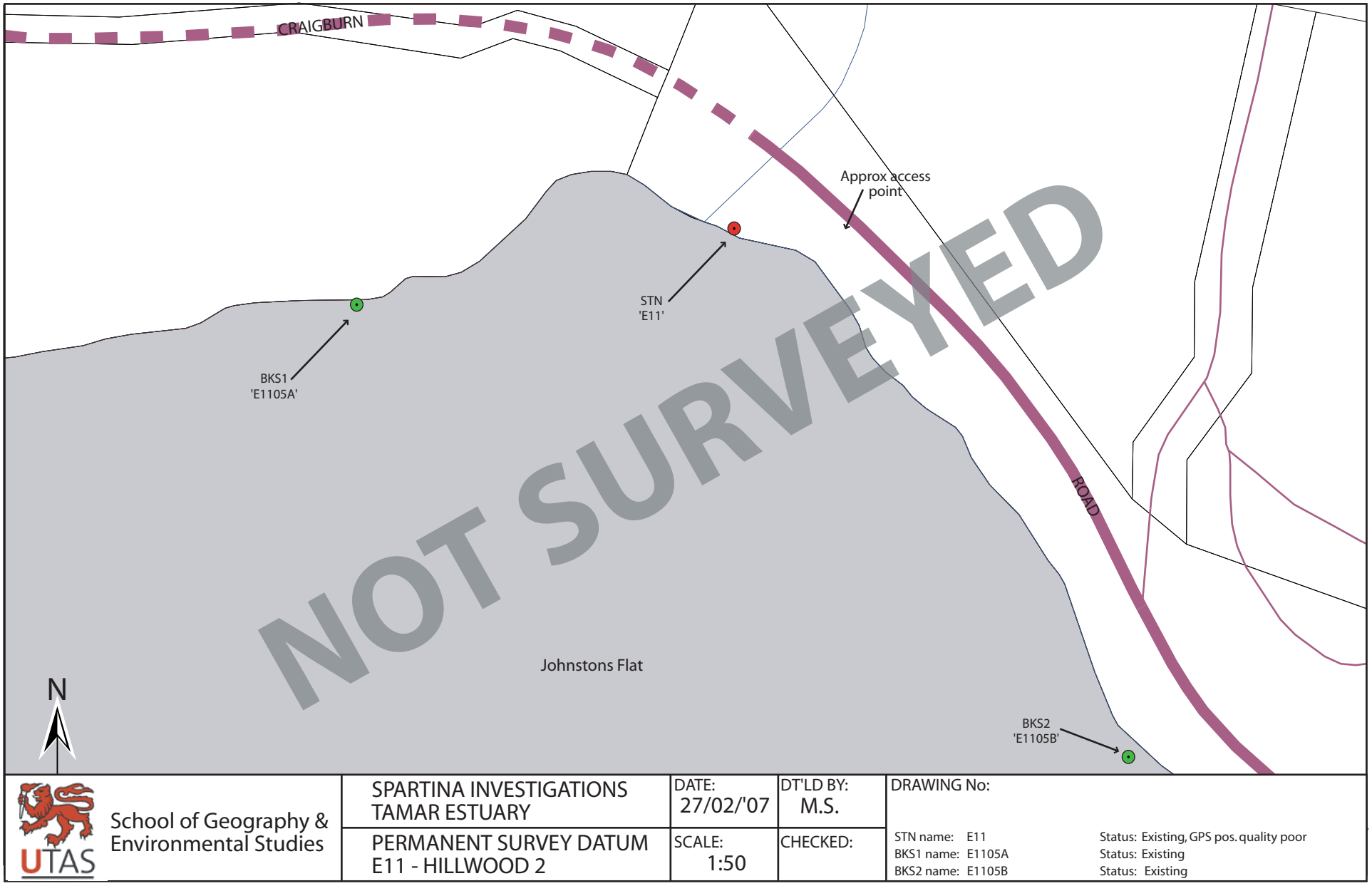


Figure 3.28: Transect W11, Hillwood 2.

Table 3.26: Benchmark information for transect W16

W1605 (W016 – Deviot 1)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	494905.957	5433589.331	62.0200
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	6.4628	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Short star picket level with ground surface			
Locality	Opposite 219 Deviot-Gravelly Beach Road, with position indicated by a white arrow on the estuary side of the road. Star picket is located in the road reserve 2 meters from the mark at right-angles to the road			
Sight access	Accessible by Two wheel drive vehicle.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
W1605A	494847.7072	5433714.012	8.3706	334.5730	137.66
Description	Top edge of culvert, marked by white survey paint.			

Table 3.27: Benchmark information for transect W17

W1705 (W17 – Deviot 2)				
Horizontal Information				
	Zone	**Easting**	**Northing**	**Transect bearing**
	55	494066.5508	5435744.756	50.0108
	Datum		**Survey Class**	**Order**
	Geocentric Datum of Aust 1994		B	Second
Vertical Information				
	Ht	**Datum**	**Survey Class**	**Order**
	5.978	Aust Height Datum (Tas) 1983	Satellite - GPS	Third
Mark Details				
Description	Short star picket level with ground surface			
Locality	Opposite south-eastern boundary of 601 Deviot-Gravelly Beach Road, with position indicated by a white arrow on the estuary side of the road. Star picket is located in the road reserve 5 meters from the mark at right-angles to the road.			
Sight access	Accessible by Two wheel drive vehicle.			
Backsight Information				
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**
W1705B	493985.5393	5435795.254	6.8761	221.2905	95.466
Description	Top of concrete drain, marked by white survey paint.			

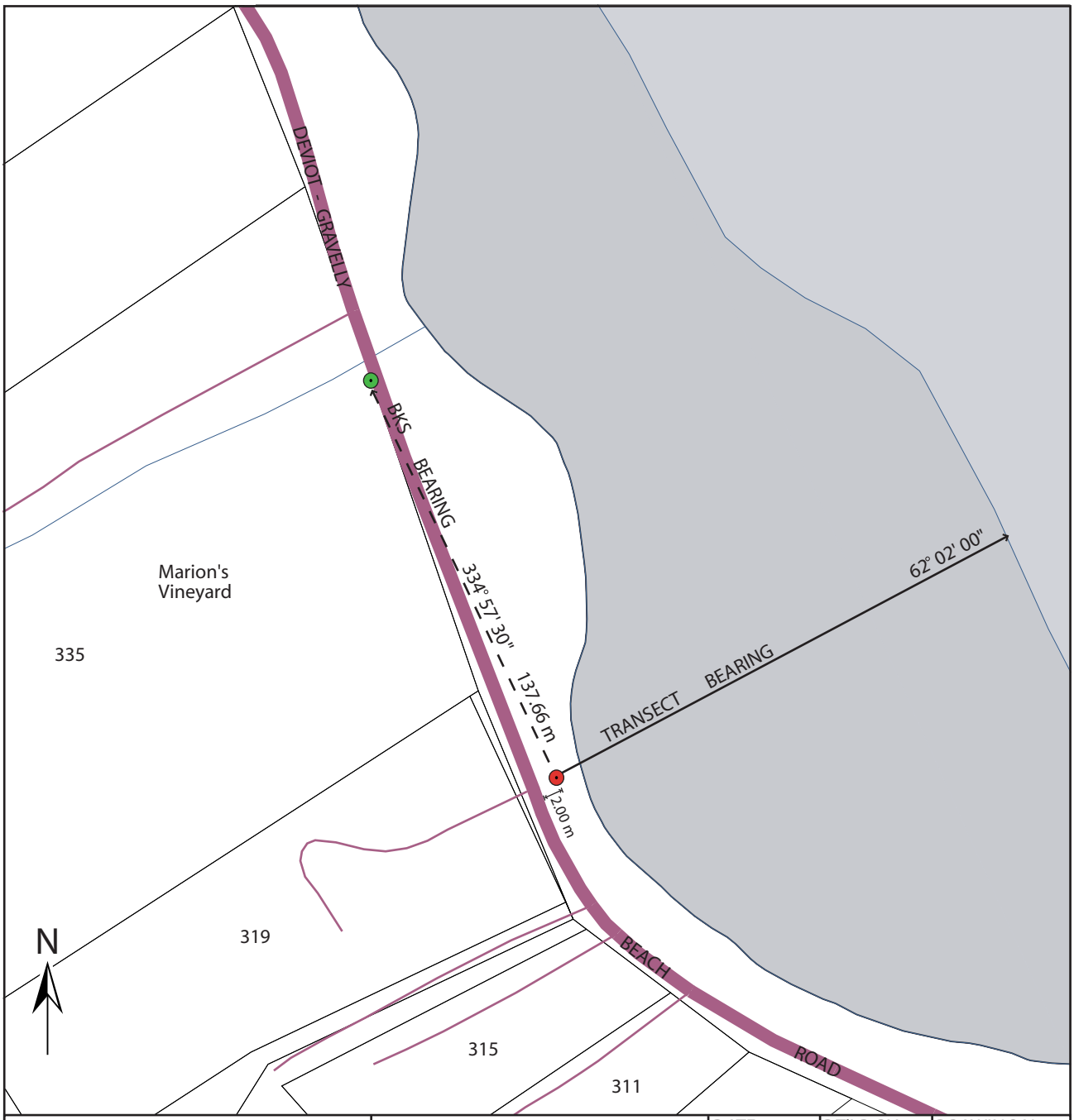


Figure 3.29: Transect W16, Deviot.

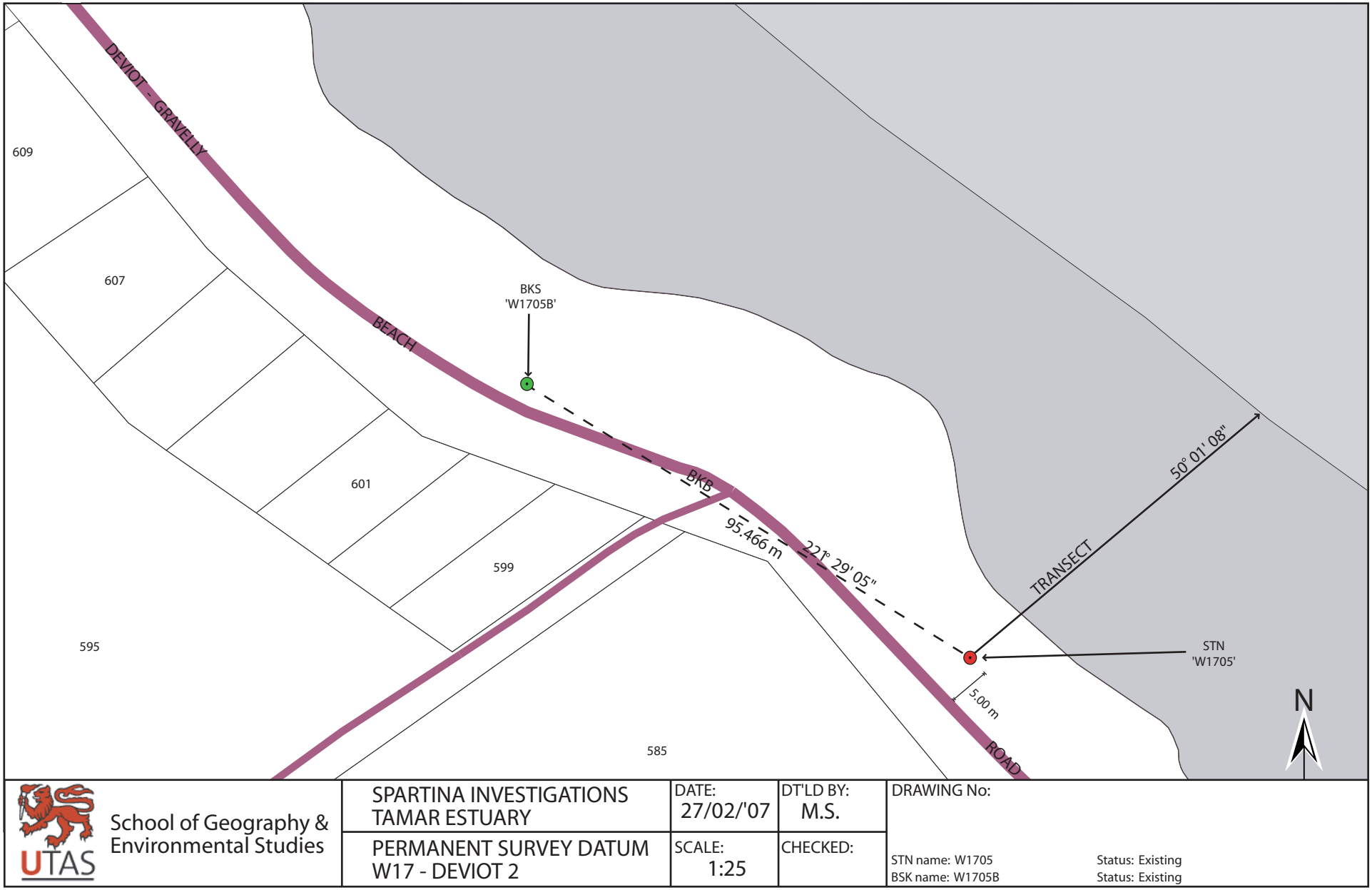


Figure 3.30: Transect W17, Deviot.

Table 3.28: Benchmark information for transect W18

SV DEVILS ELBOW (W18 – Devil's Elbow)						
Horizontal Information						
	Zone	**Easting**	**Northing**		**Transect bearing**	
	55	491419.5109	5439191.158		-	
	Datum		**Survey Class**		**Order**	
	Geocentric Datum of Aust 1994		B		Second	
Vertical Information						
	Ht	**Datum**		**Survey Class**		**Order**
	1.9795	Aust Height Datum (Tas) 1983		Satellite - GPS		Third
Mark Details						
Description	S.V. Plug in creek. Road reserve just after bridge on Rowella road. Setup over this point is not possible, so an offset will have to be used.					
Locality	Rowella Rd, Devils Elbow.					
Sight access	2WD vehicle access.					
Backsight Information						
	Easting	**Northing**	**Ht**	**Bearing**	**Dist**	**Description**
SPM10672	491631.599	5438184.596	1.9	-	-	*

* Devils Elbow pontoon - Refer to http://surcom.dpiw.tas.gov.au. This location has not been surveyed.

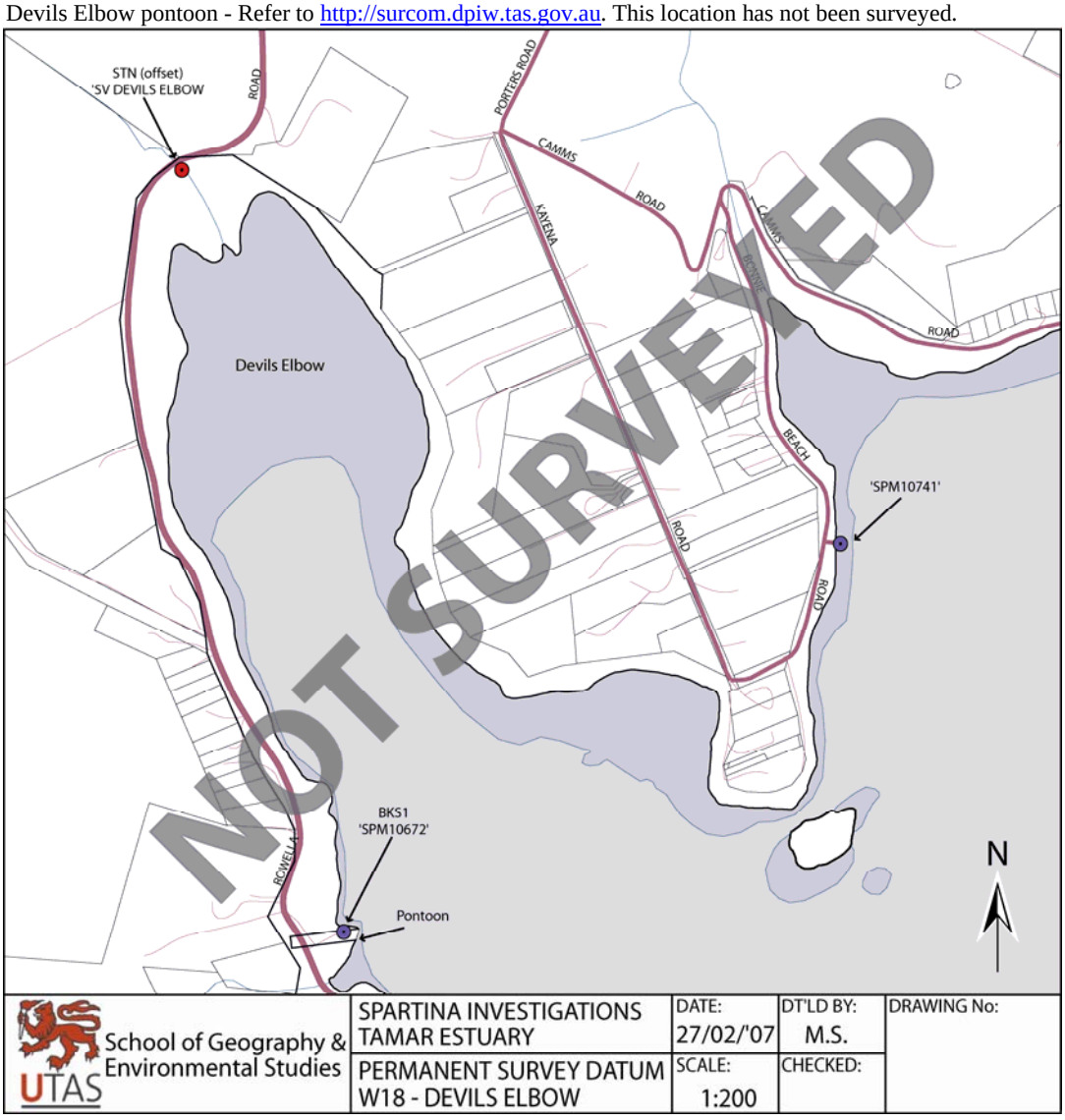


Figure 3.31: Transect W18, devils Elbow.

4 Results

4.1 Cross-Sectional Profiles

4.1.1 Profile Drawings – 2005/6 Surveying

In this section, scale diagrams of all cross sectional profiles form *Spartina* marshes are presented. Major findings and implications of the research are discussed at length elsewhere and have not been included in this report, however, a general discussion of major findings is included.

All 16 surveyed profiles from the Tamar Estuary are similar with respect to general cross sectional surface morphology and topography. Average gradient of the *Spartina* marsh surface was observed to be typically between 0 and 5 degrees from the horizontal. All profiles generally exhibited a flat to slightly concave-up upper marsh, a convex-up ridge in the outer mid marsh, and a relatively steeply graded convex-up lower marsh. These characteristics appear most pronounced in marshes upstream of Gravelly Beach (Figure 2.1). Closer examination of marshes with well developed creek systems, such as W04 (Figure 4.4) and W06 (Figure 4.6), show that the marsh surface is convex-up overall with a large number of platform elements which are individually concave-up, separated by channels of various orders. In many instances channels have cut down to the pre-*Spartina* surface.

A distinction can be made between marshes upstream of Gravelly Beach and those downstream based on the degree of vertical development and the morphology of the outer marsh. Marshes upstream of Gravelly Beach, referred to hereafter as type-1 marshes, have increased vertically relative to the pre-*Spartina* surface elevation to a greater extent than those of the lower estuary, type-2 marshes. Surface topography and marsh development of type-1 marshes appear independent of the pre-*Spartina* surface morphology, whereas type-2 marshes are considerably thinner with surface topography generally dictated by the underlying pre-*Spartina* surface, often with the basement outcropping along the transect.

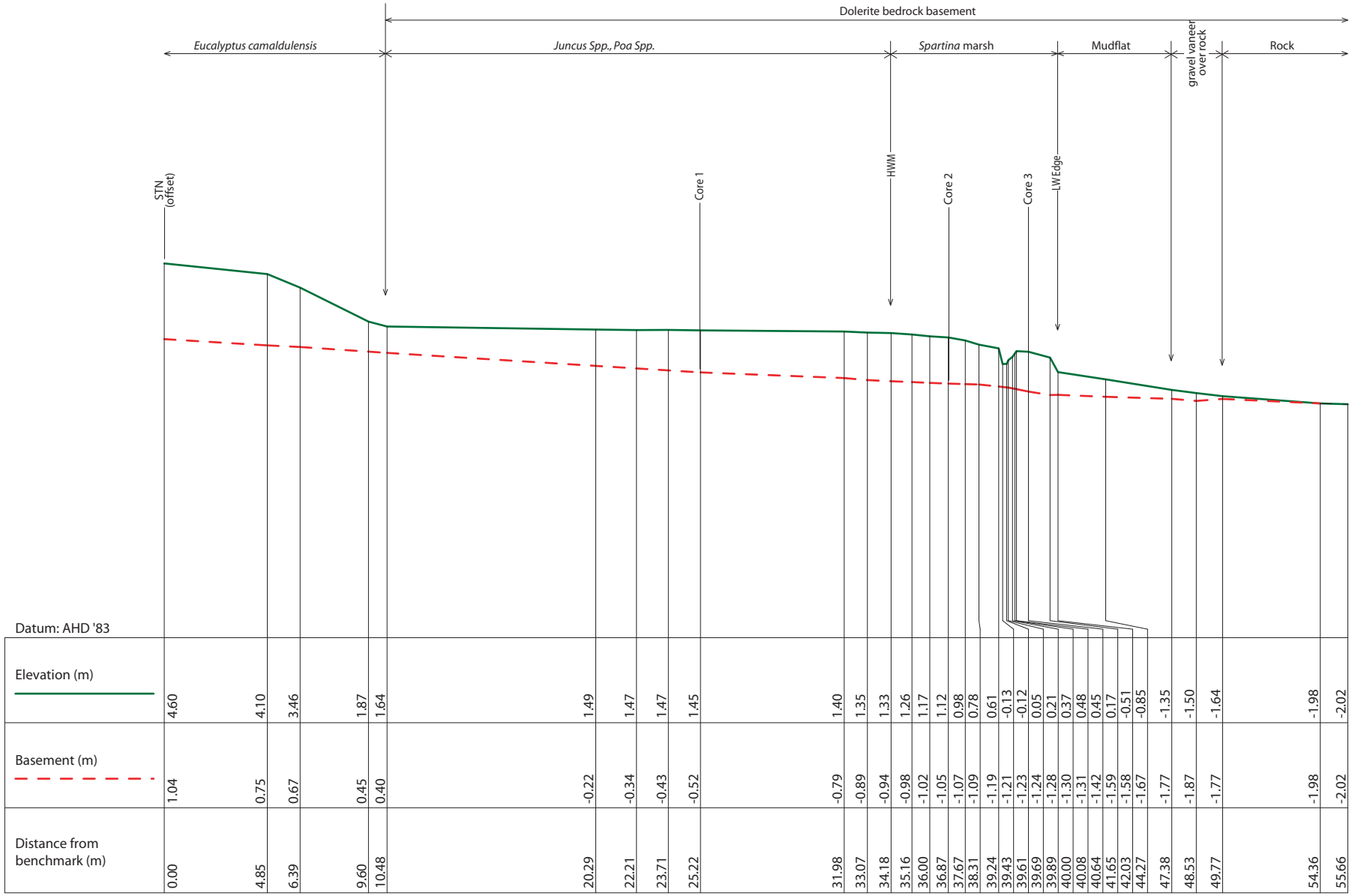
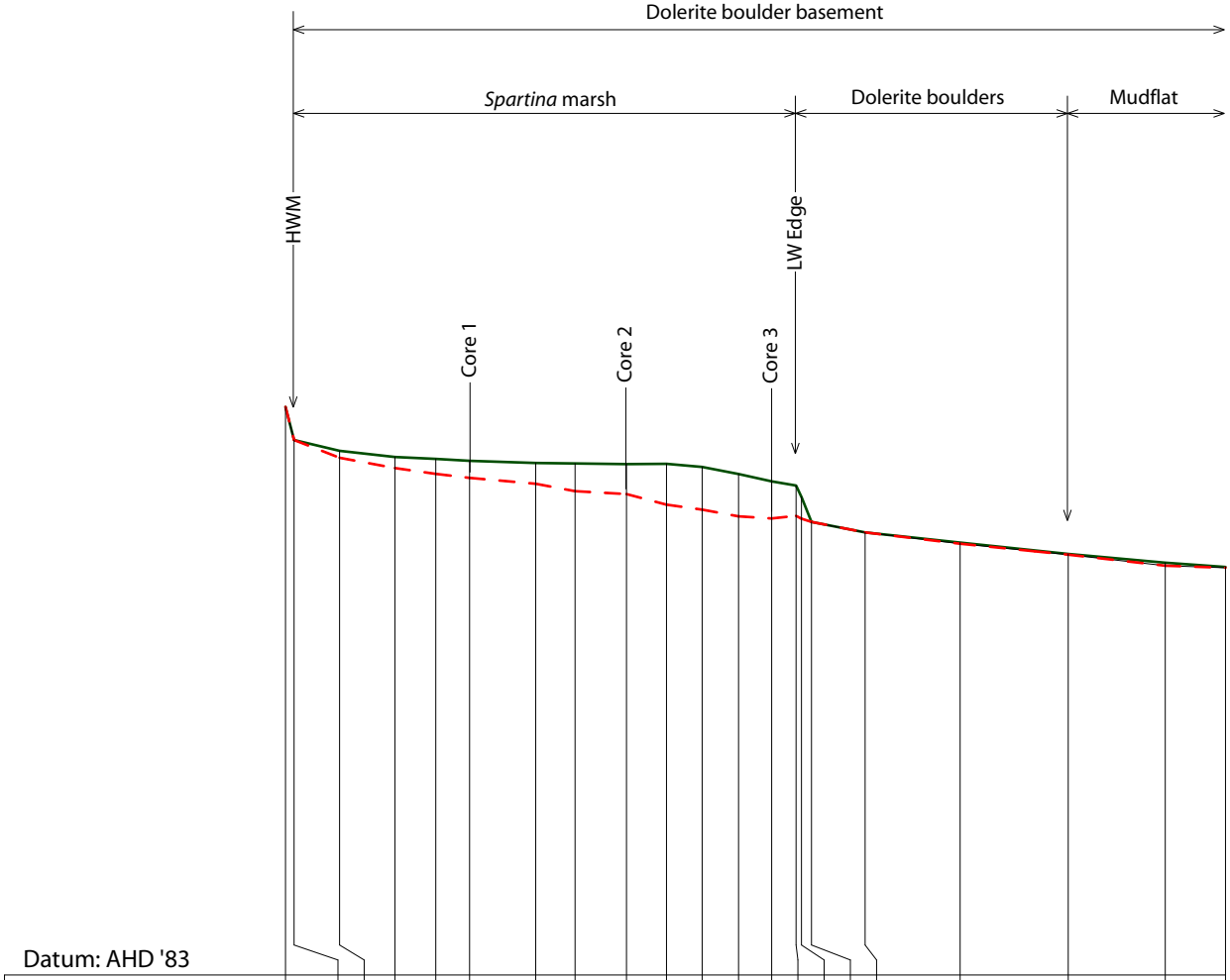


Figure 4.1: Profile of W01, Legana.

Scale Horizontal 1:200 Vertical 1:200



Datum: AHD '83																					
Surface (m)	2.17	1.28	1.00	0.83	0.78	0.73	0.67	0.66	0.64	0.65	0.56	0.38	0.18	0.07	-0.24	-0.90	-1.18	-1.46	-1.76	-1.99	-2.11
Basement (m)	2.17	1.28	0.81	0.54	0.38	0.27	0.12	-0.08	-0.16	-0.44	-0.58	-0.75	-0.81	-0.74	-0.82	-0.90	-1.18	-1.49	-1.78	-2.07	-2.13
Distance from benchmark (m)	0.00	0.23	1.44	2.92	4.01	4.91	6.68	7.73	9.10	10.17	11.12	12.09	12.98	13.63	13.77	14.04	15.47	18.00	20.89	23.48	25.09

Scale Horizontal 1:200 Vertical 1:200

Figure 4.2: Prrofile of E01, Dilston.

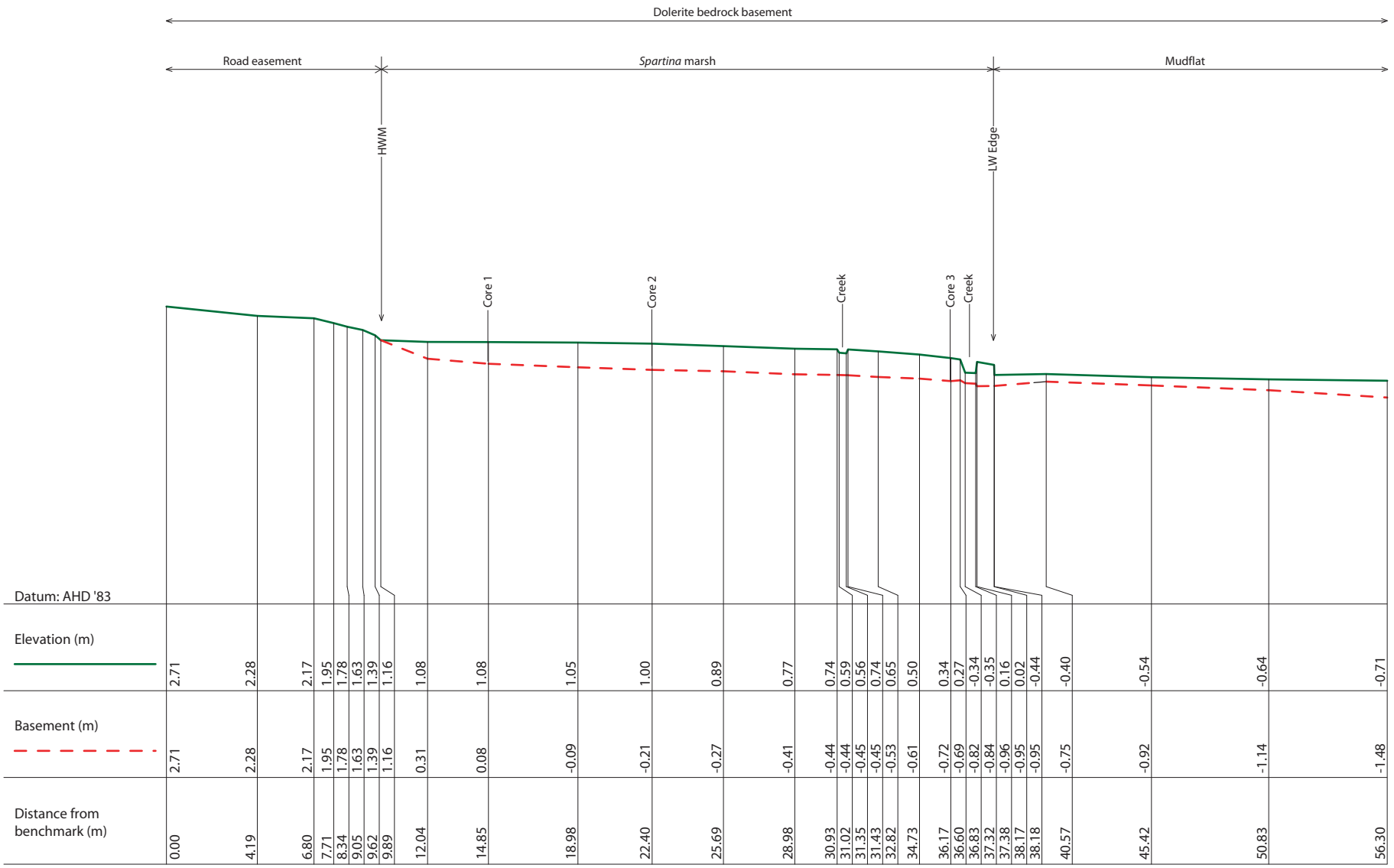


Figure 4.3: Profile of W03, Loch Lea.

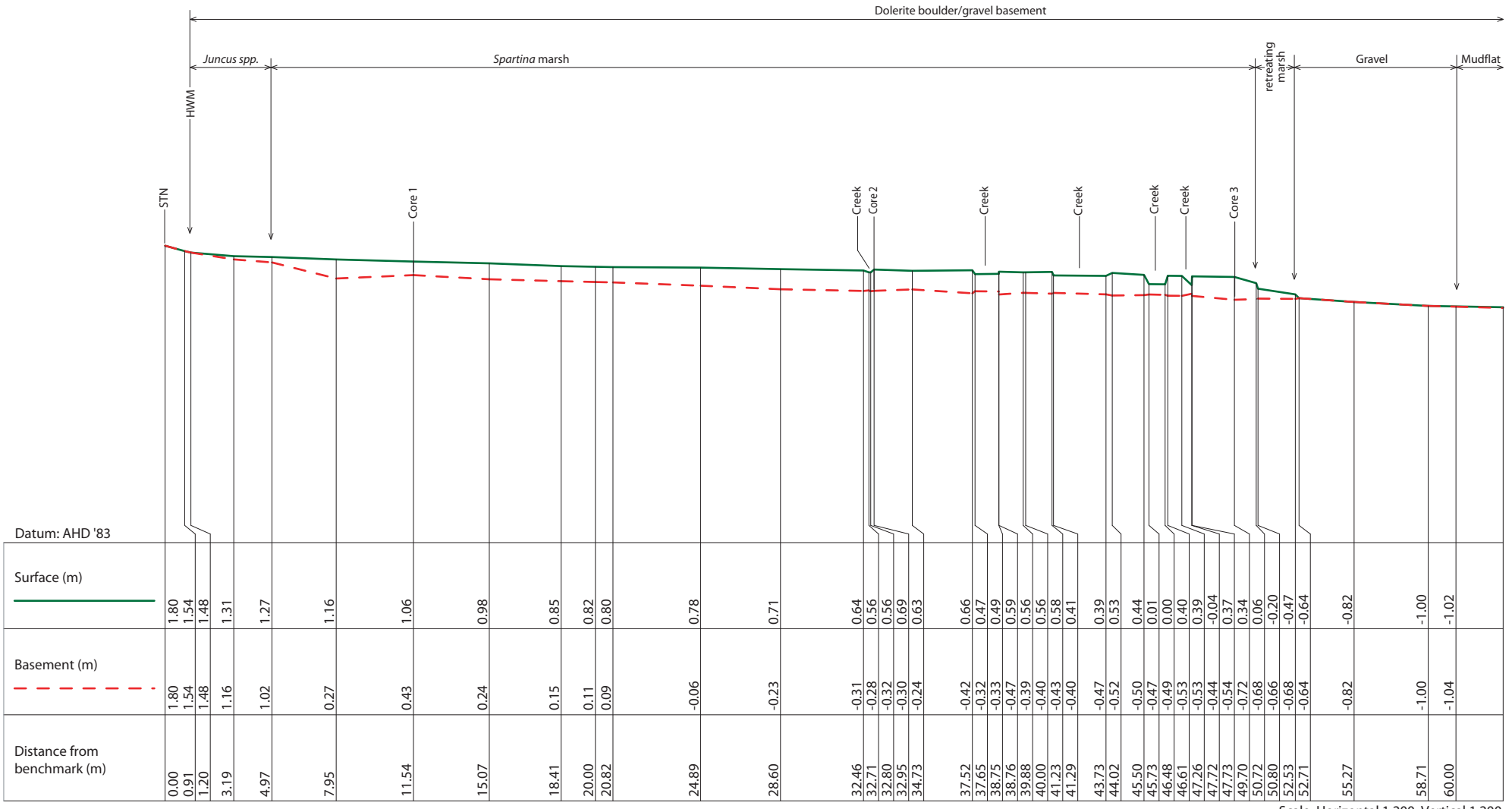


Figure 4.4: Profile of W04, Rosevears.

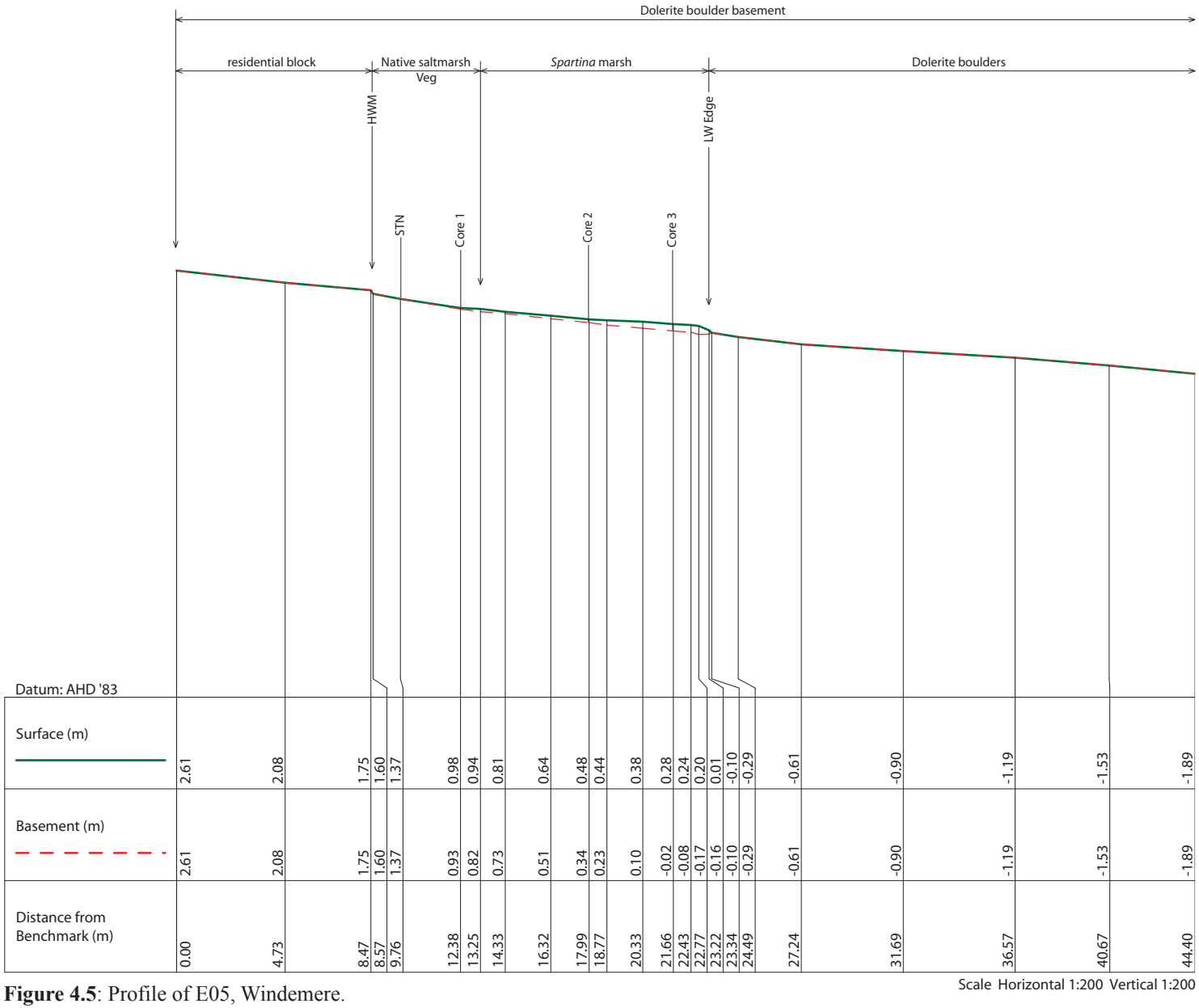


Figure 4.5: Profile of E05, Windemere.

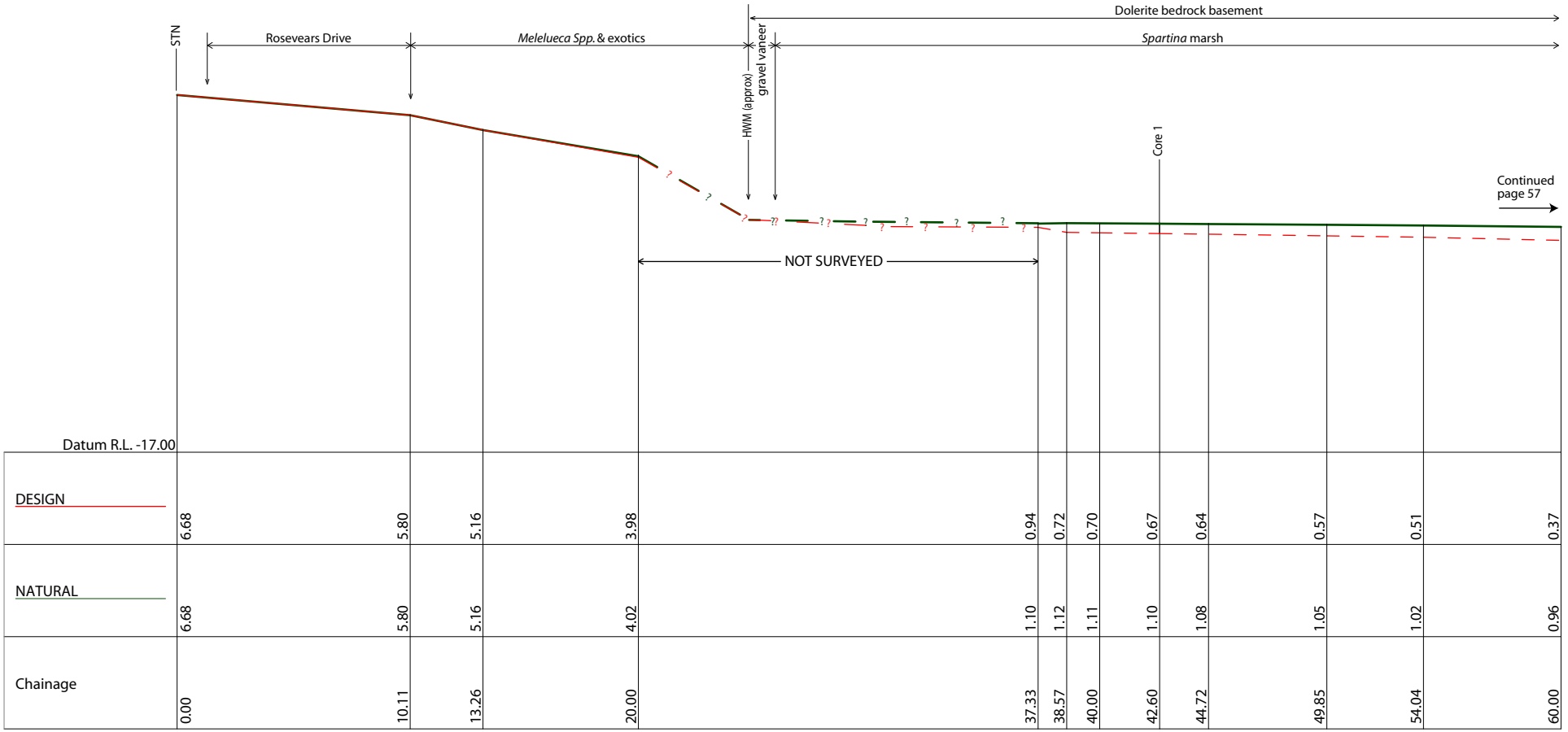


Figure 4.6: Profile of W06, Rosevears, section 1 of 4.

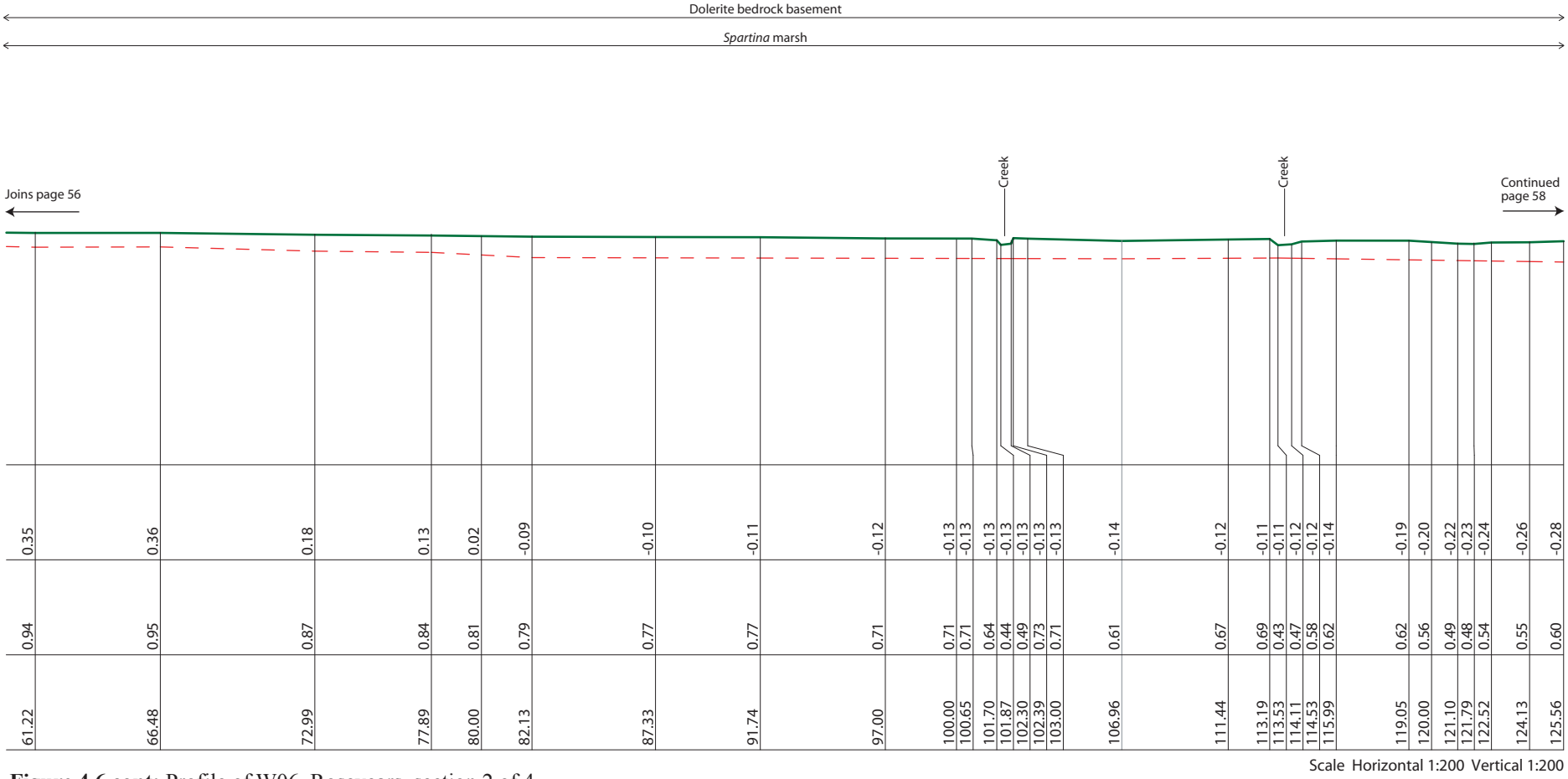


Figure 4.6 cont: Profile of W06, Rosevears, section 2 of 4.

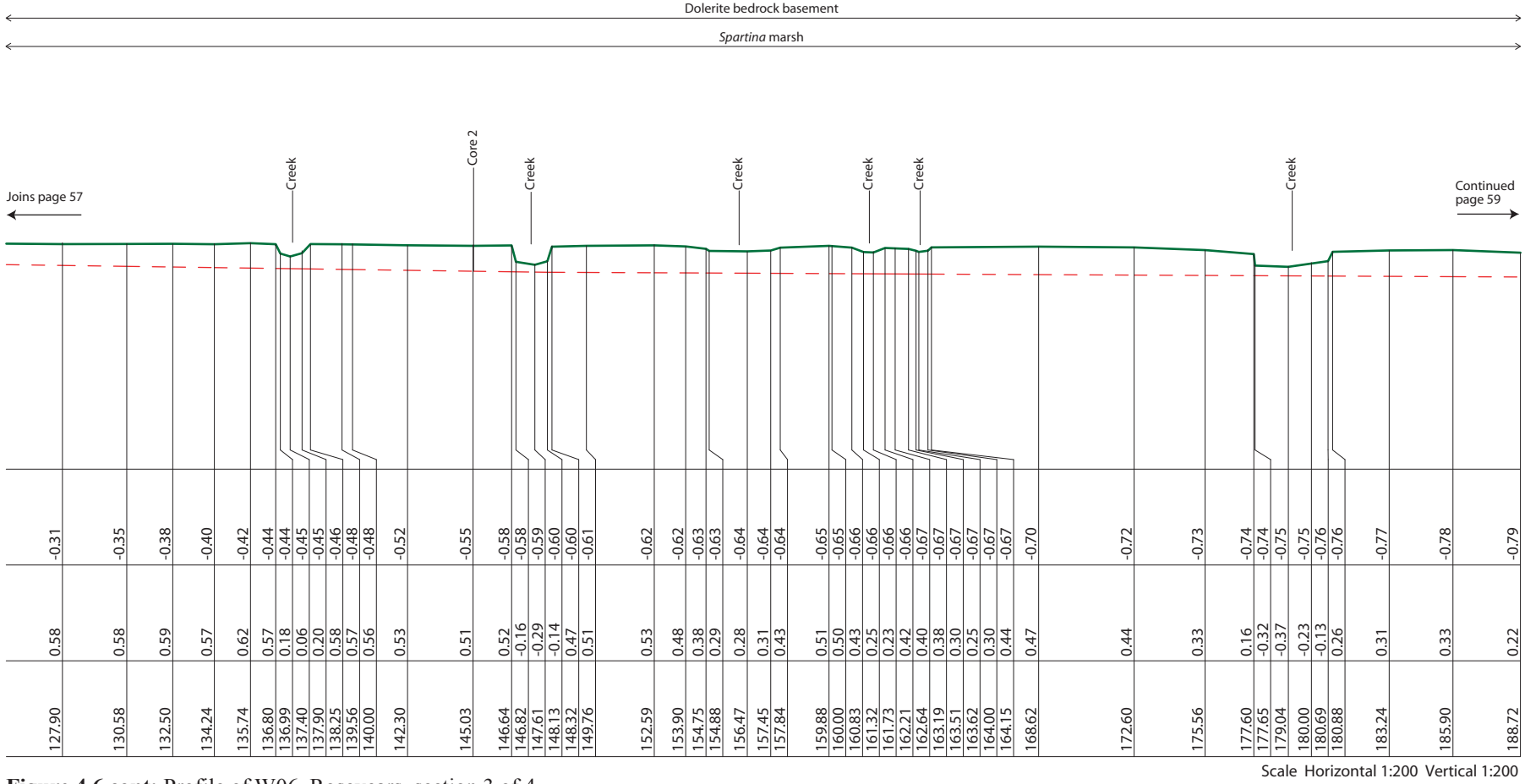


Figure 4.6 cont: Profile of W06, Rosevears, section 3 of 4.

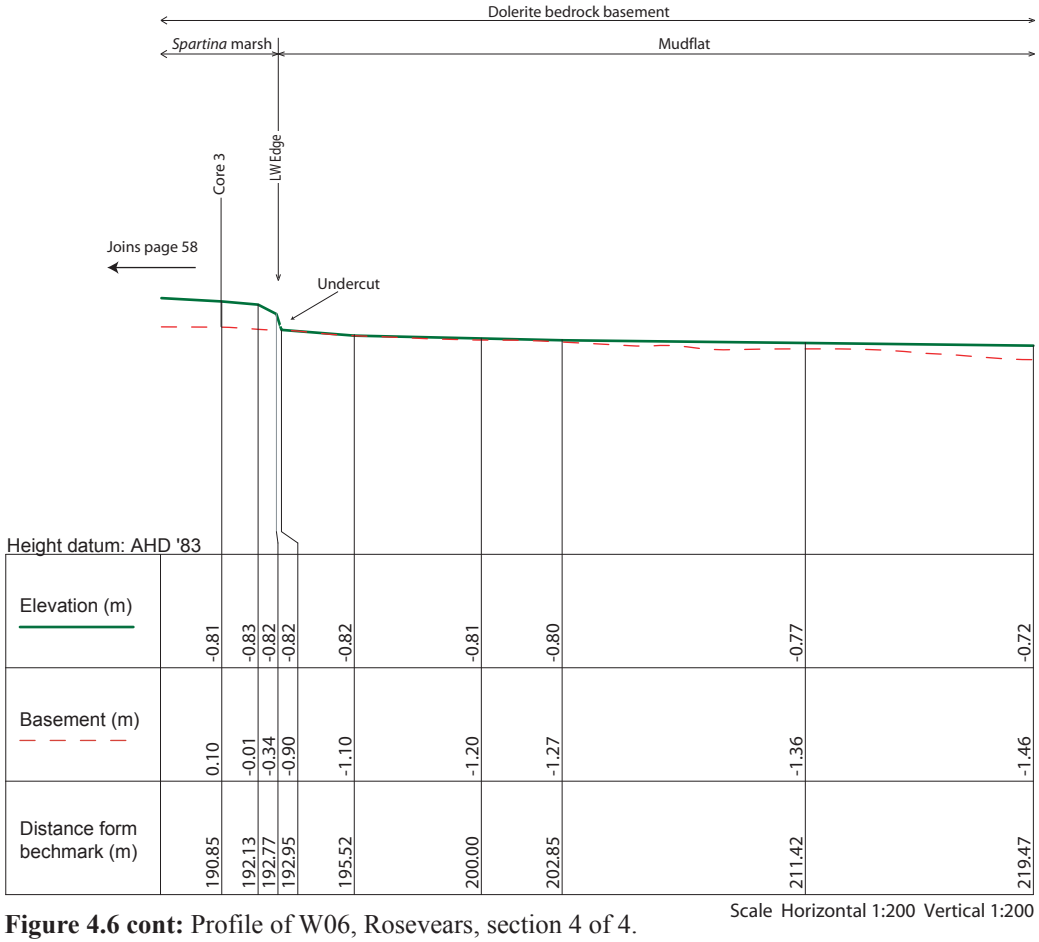


Figure 4.6 cont: Profile of W06, Rosevears, section 4 of 4.

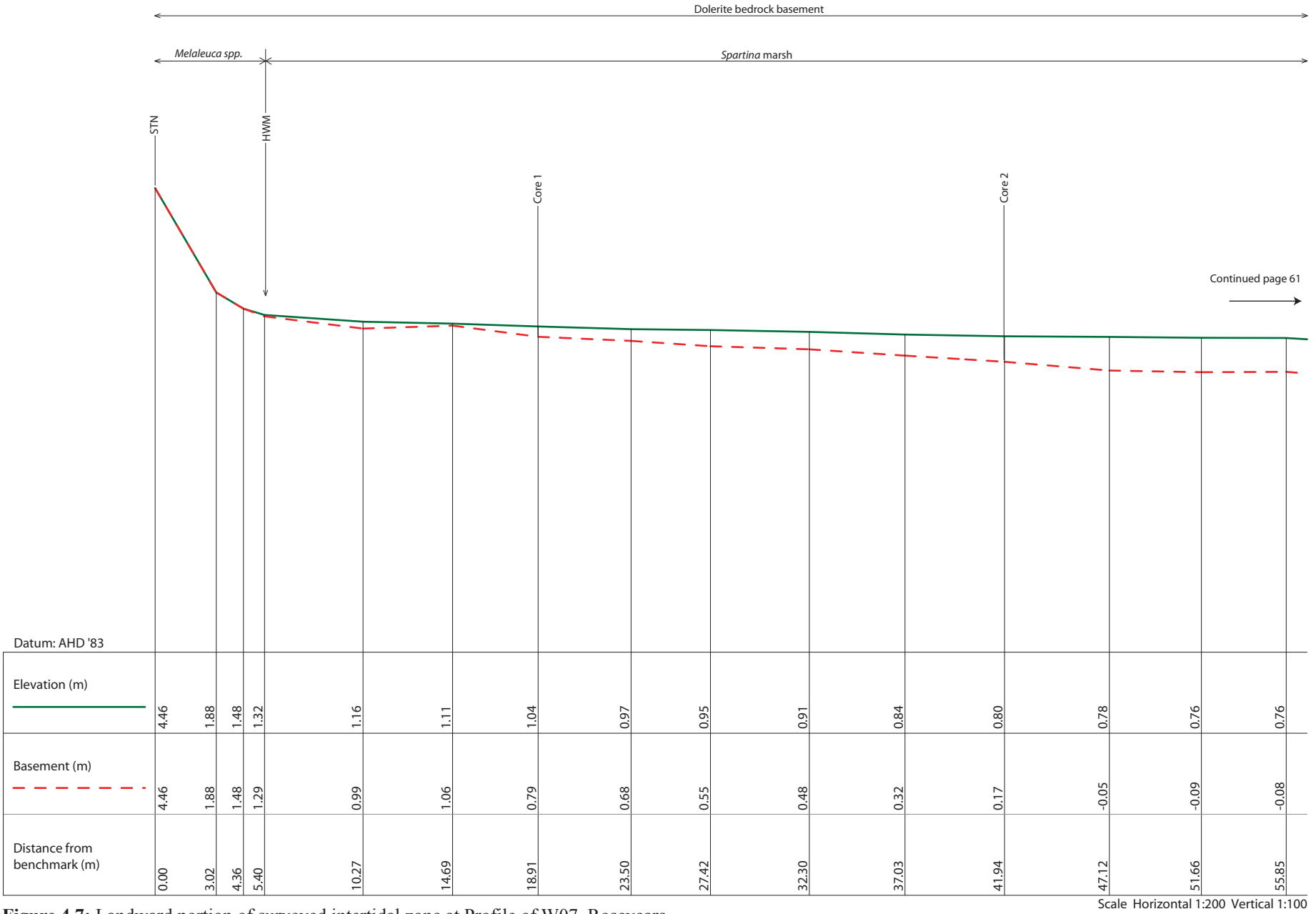


Figure 4.7: Landward portion of surveyed intertidal zone at Profile of W07, Rosevears.

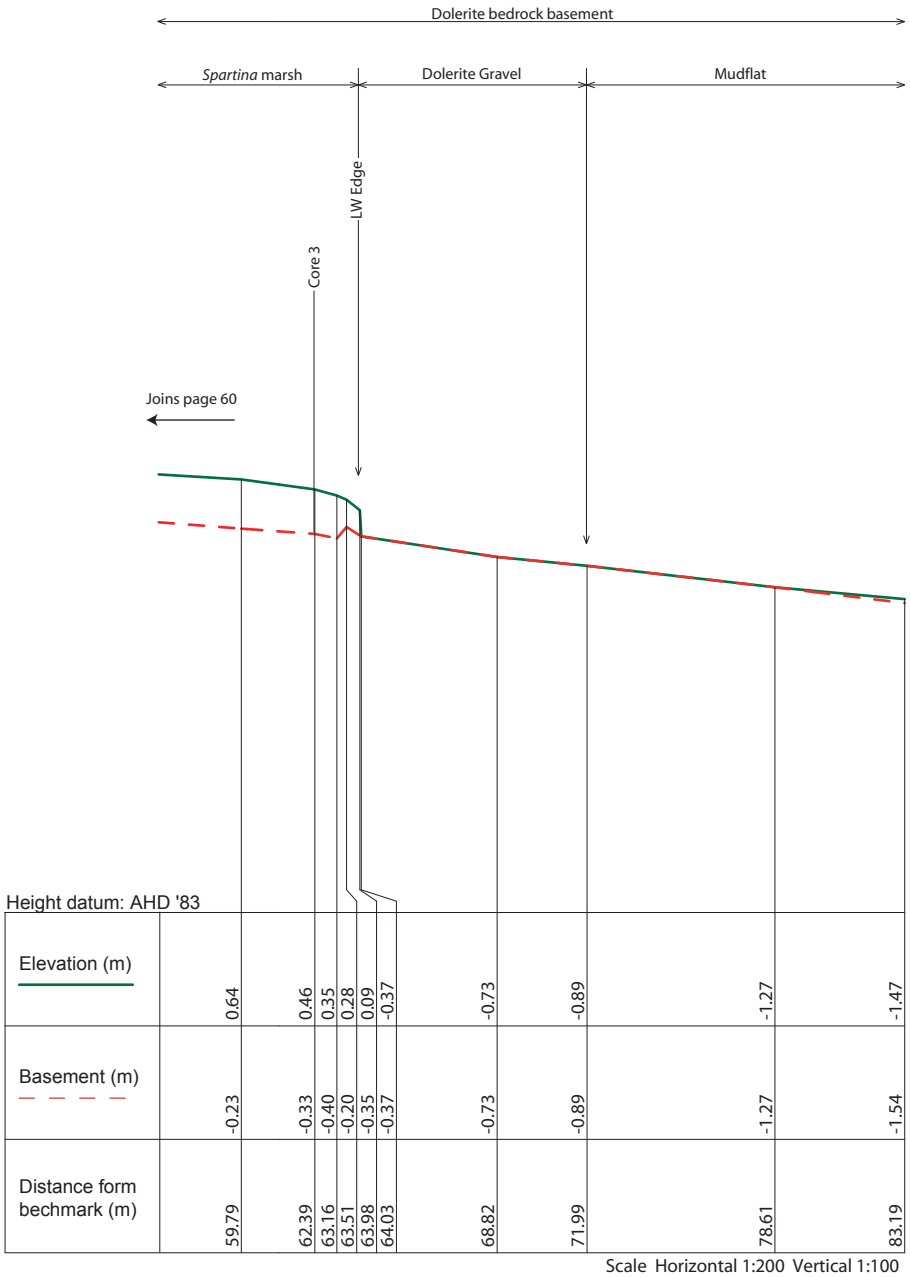


Figure 4.7 Cont.: Seaward portion of surveyed intertidal zone at Profile W07, Rosevears.

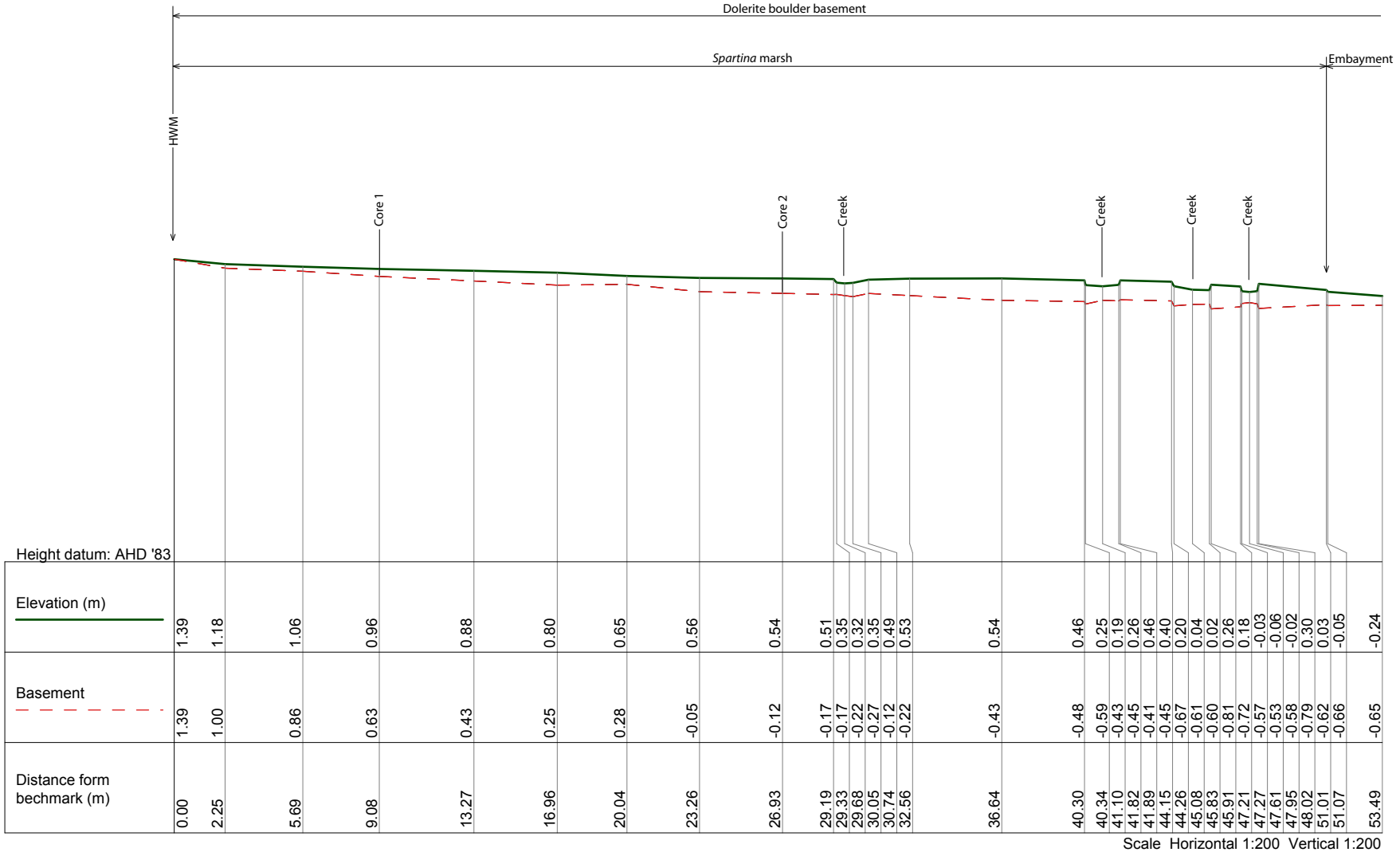


Figure 4.8: Landward portion of surveyed intertidal zone at Profile W08, Rosevears.

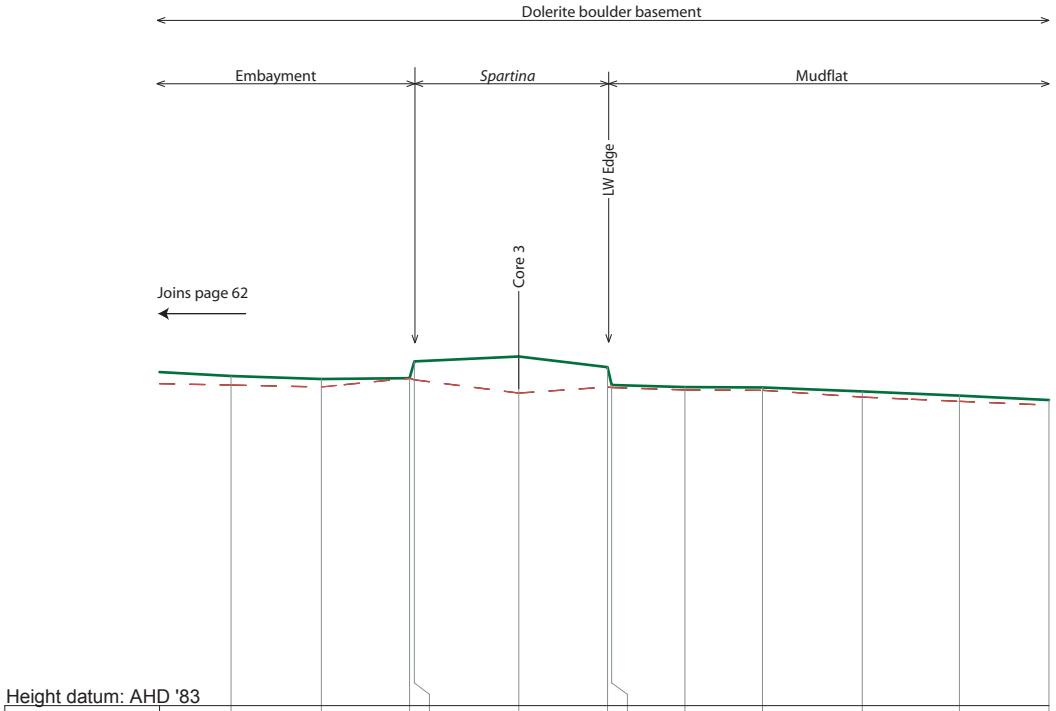


Figure 4.8 Cont: Seaward portion of surveyed intertidal zone at Profile W08, Rosevears.

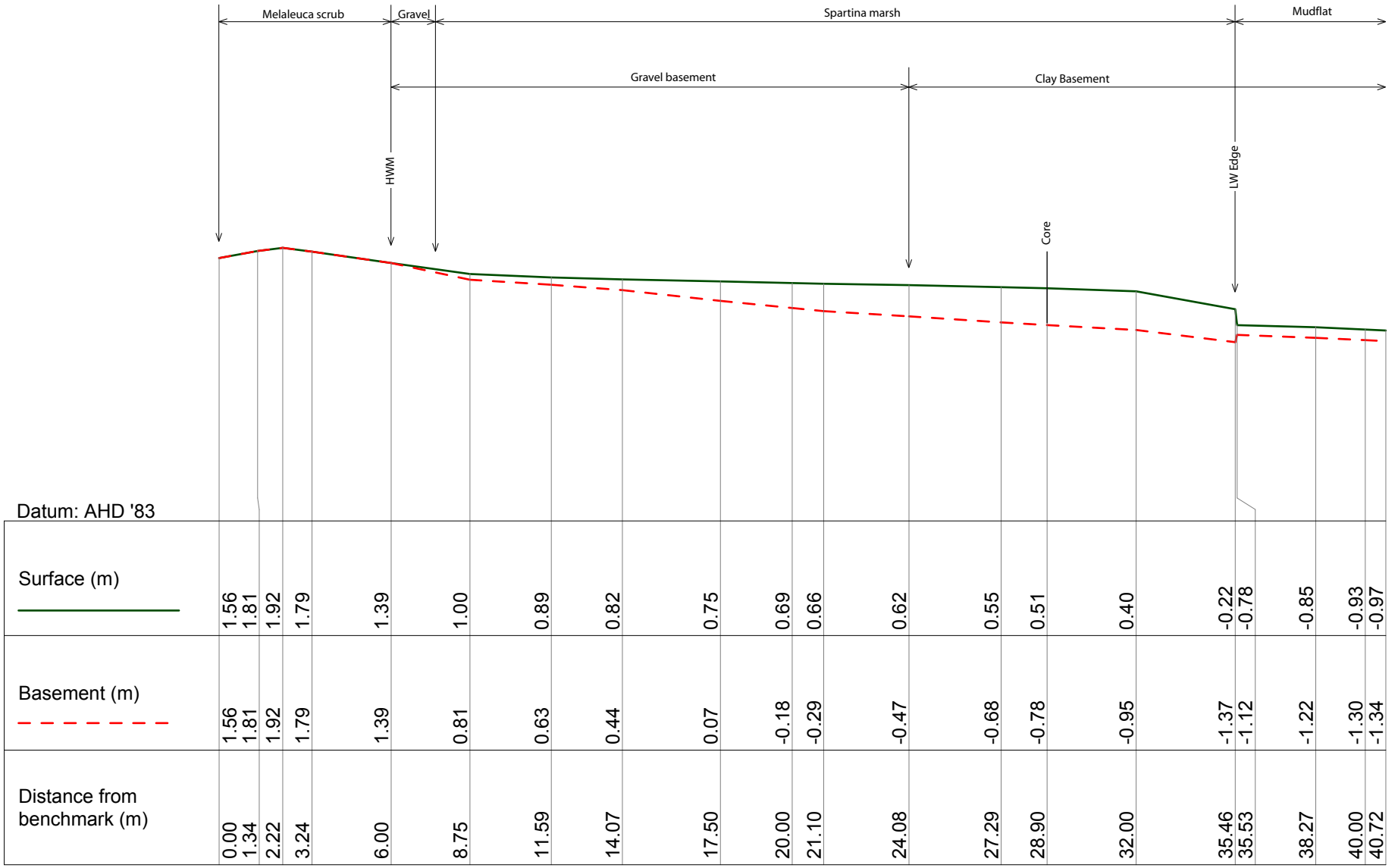
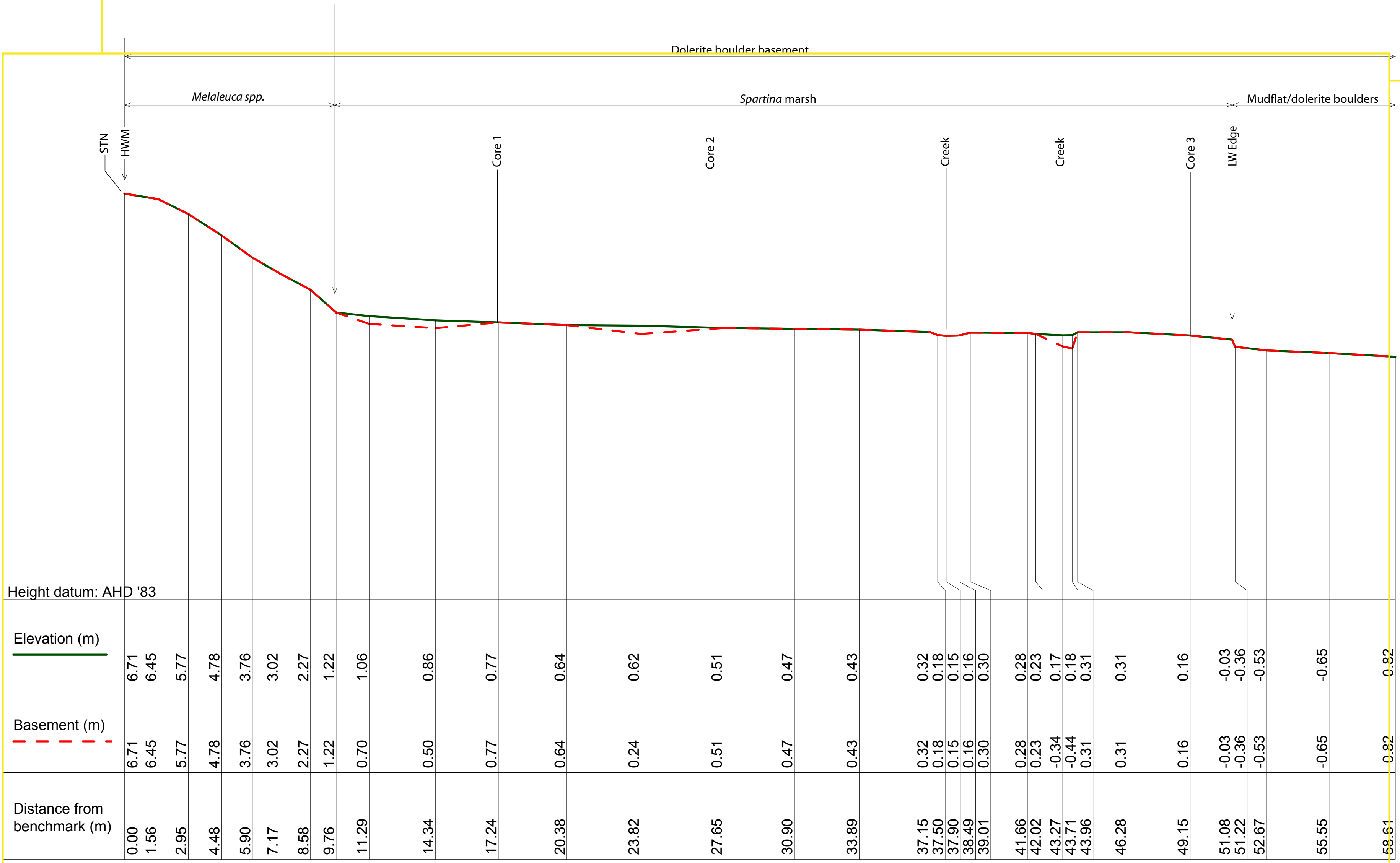


Figure 4.9: Profile E06, Native Point.

Scale Horizontal 1:200 Vertical 1:200



Distance from benchmark (m)	Elevation (m)	Basement (m)
0.00	6.71	6.71
1.56	6.45	6.45
2.95	5.77	5.77
4.48	4.78	4.78
5.90	3.76	3.76
7.17	3.02	3.02
8.58	2.27	2.27
9.76	1.22	1.22
11.29	1.06	0.70
14.34	0.86	0.50
17.24	0.77	0.77
20.38	0.64	0.64
23.82	0.62	0.24
27.65	0.51	0.51
30.90	0.47	0.47
33.89	0.43	0.43
37.15	0.32	0.32
37.50	0.18	0.18
37.90	0.15	0.15
38.49	0.16	0.16
39.01	0.30	0.30
41.66	0.28	0.28
42.02	0.23	0.23
43.27	0.17	-0.34
43.71	0.18	-0.44
43.96	0.31	0.31
46.28	0.31	0.31
49.15	0.16	0.16
51.08	-0.03	-0.03
51.22	-0.36	-0.36
52.67	-0.53	-0.53
55.55	-0.65	-0.65
58.61	-0.82	-0.82

Appendix B10: Profile of W09, Blackwall.

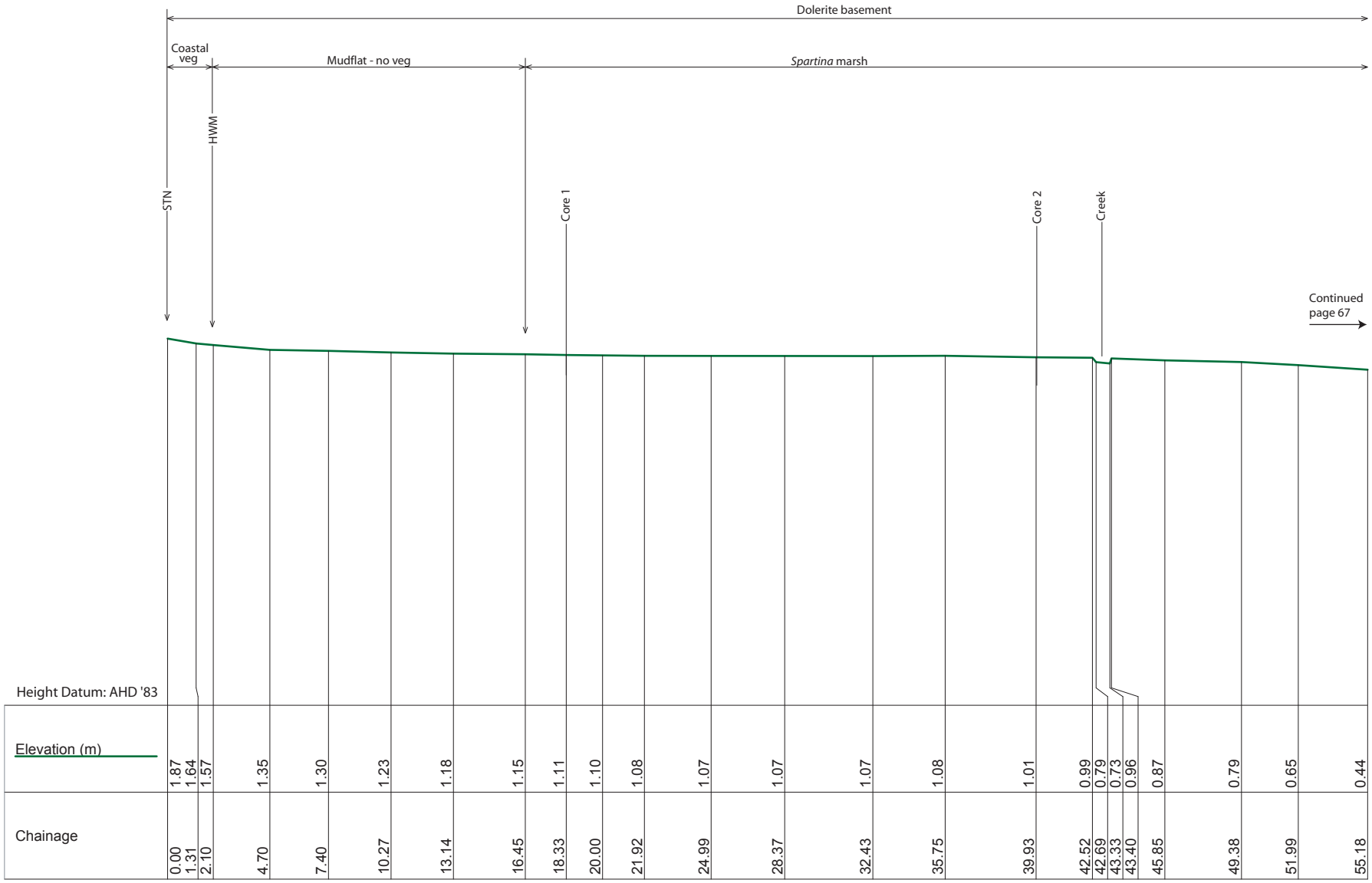


Figure 4.11: Landward portion of the surveyed intertidal zone at Profile E07, Swan Bay. NOTE: Basement data not shown.

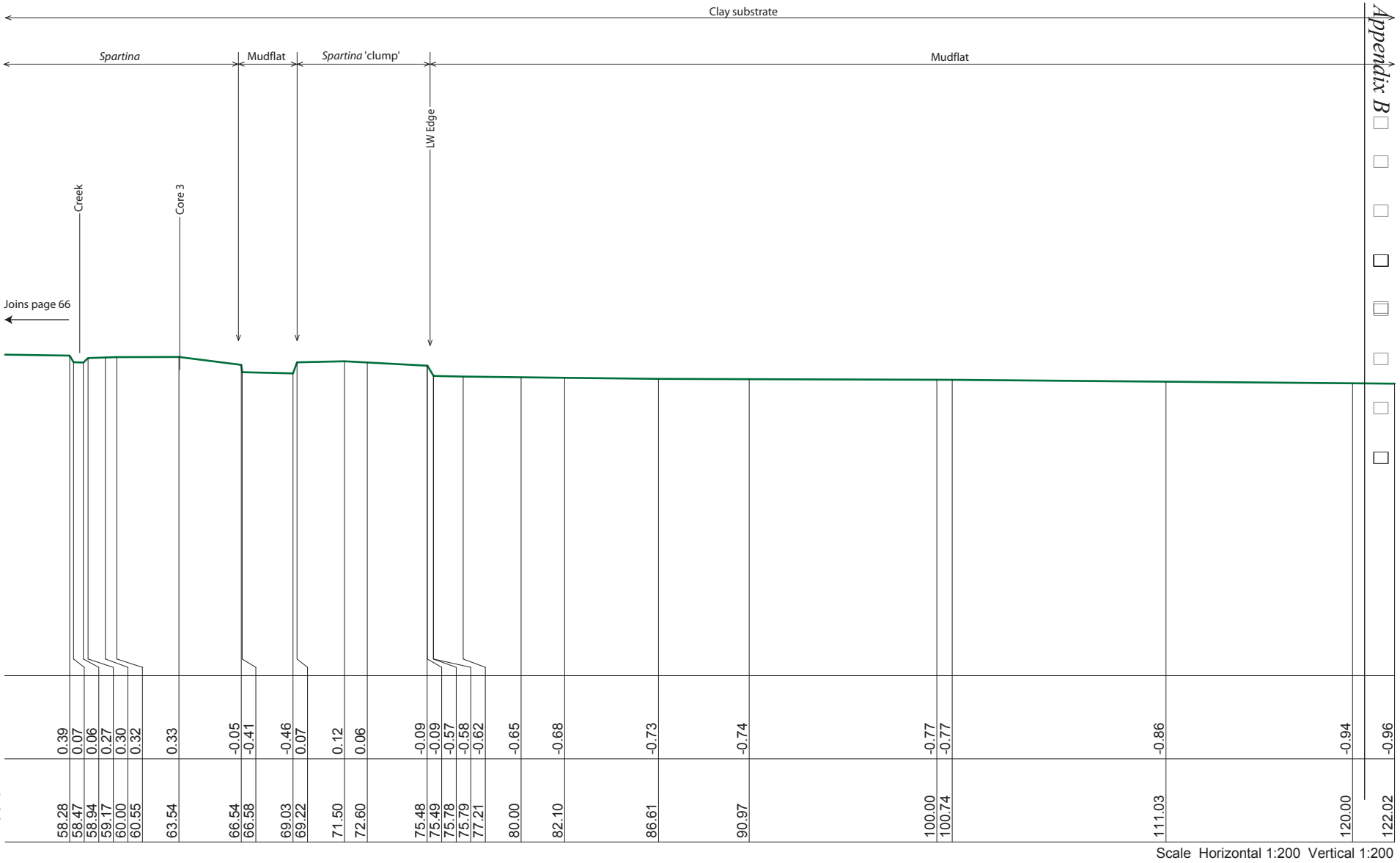


Figure 4.11 cont: Seaward portion of the surveyed intertidal zone at Profile E07, Swan Bay. NOTE: Basement data not shown.

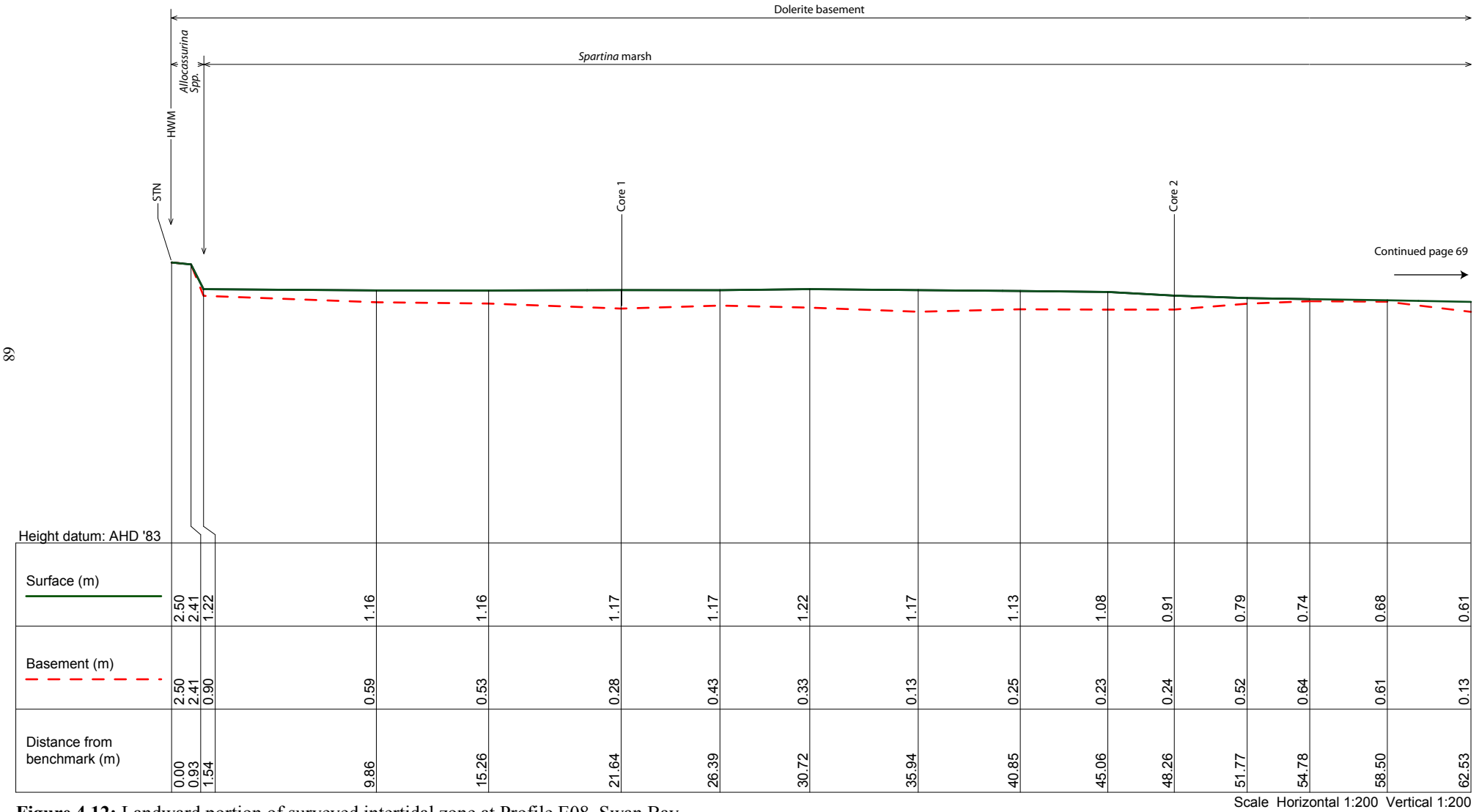


Figure 4.12: Landward portion of surveyed intertidal zone at Profile E08, Swan Bay.

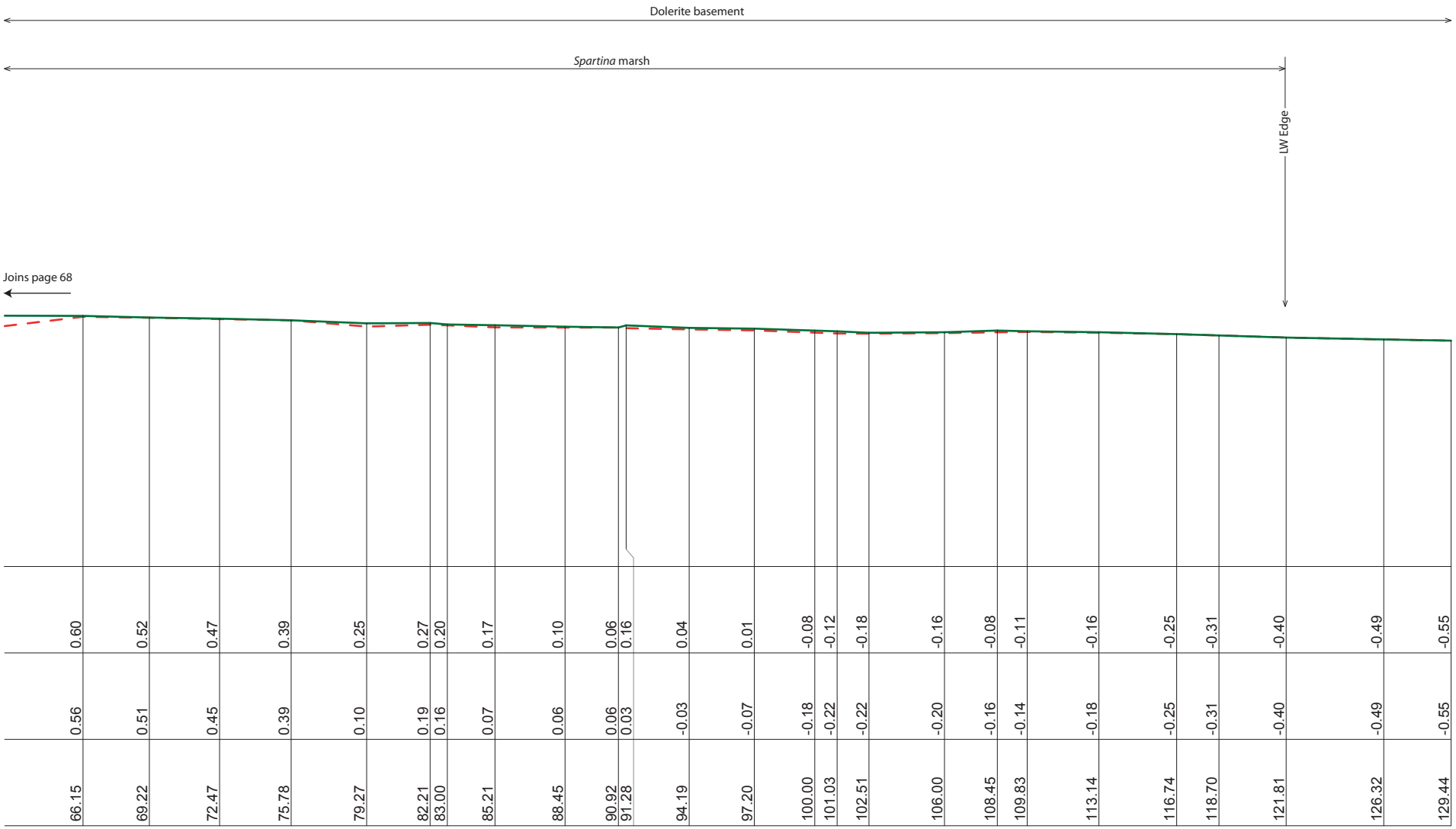


Figure 4.12 Cont: Seaward portion of surveyed intertidal zone at Profile E08, Swan Bay

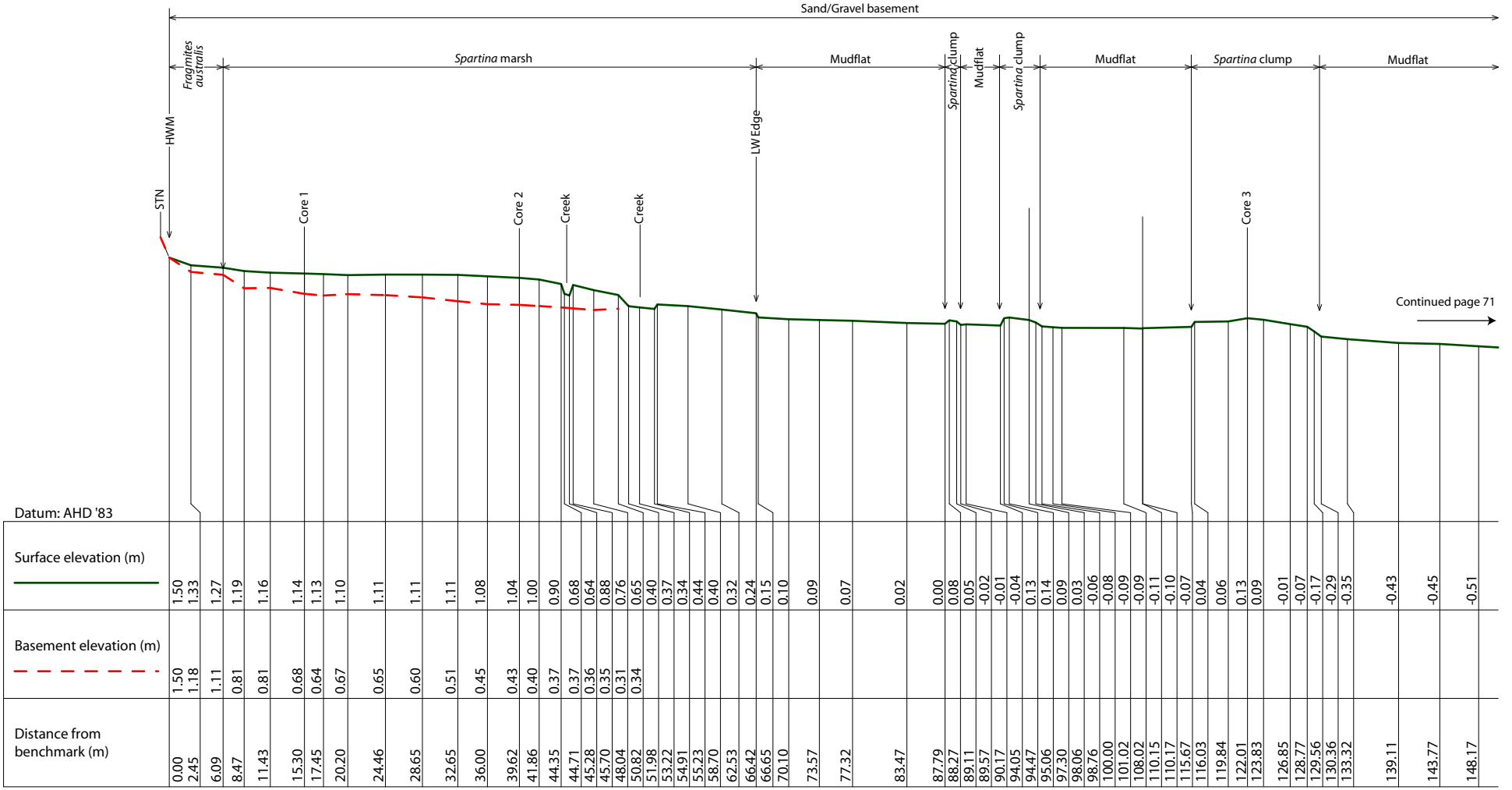


Figure 4.13: Landward portion of surveyed intertidal zone at Profile of W15, Robigana.

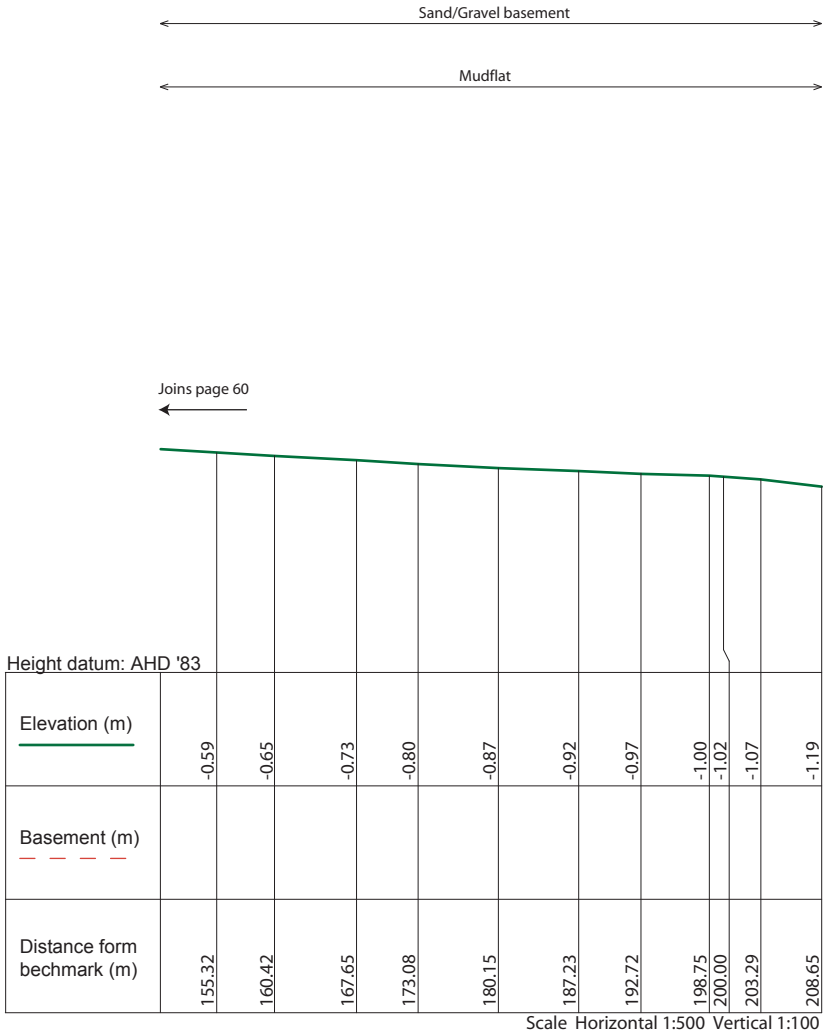


Figure 4.13 cont: Seaward portion of surveyed intertidal zone at Profile of W15, Robigana.

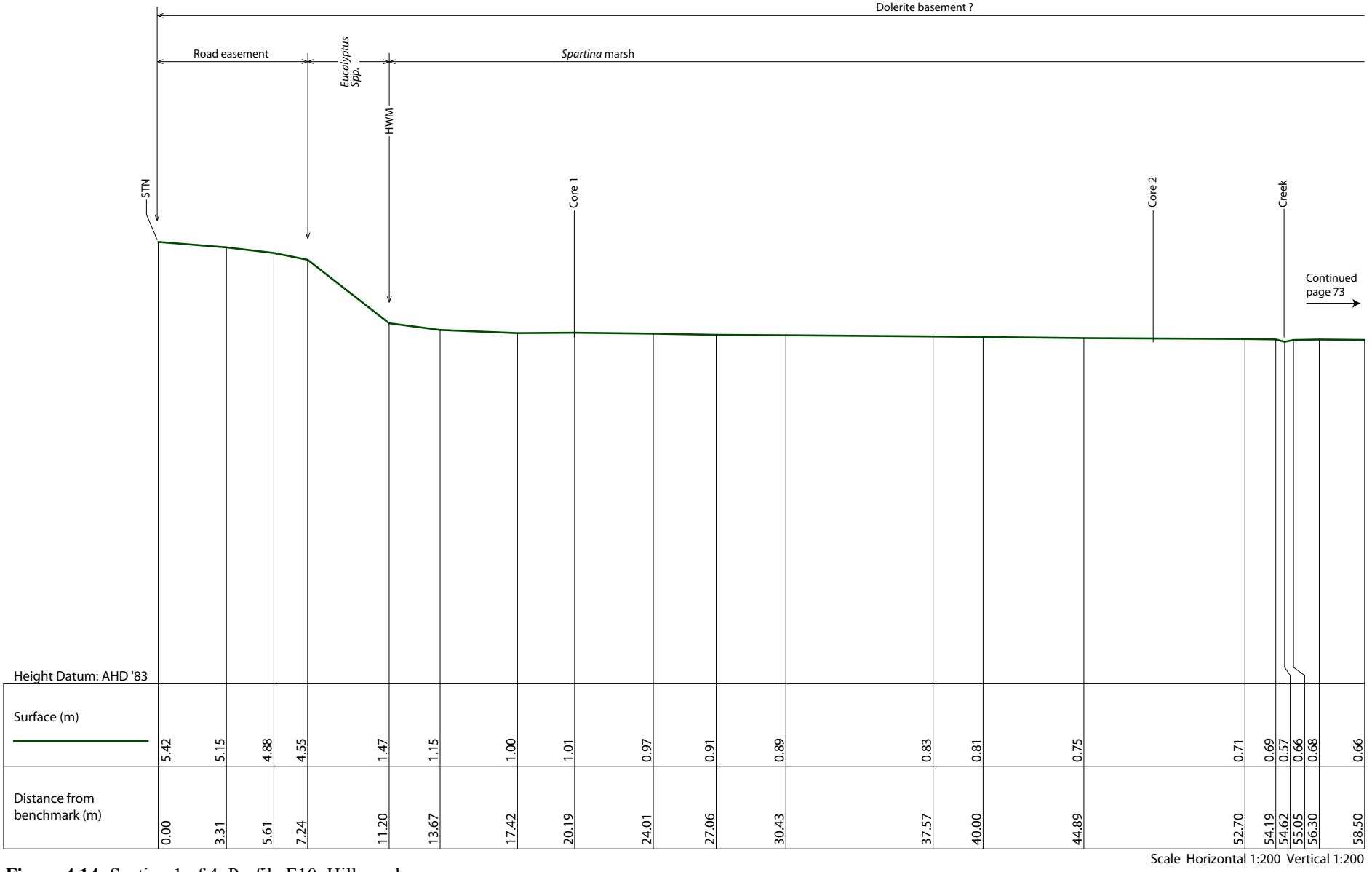


Figure 4.14: Section 1 of 4, Profile E10, Hillwood.

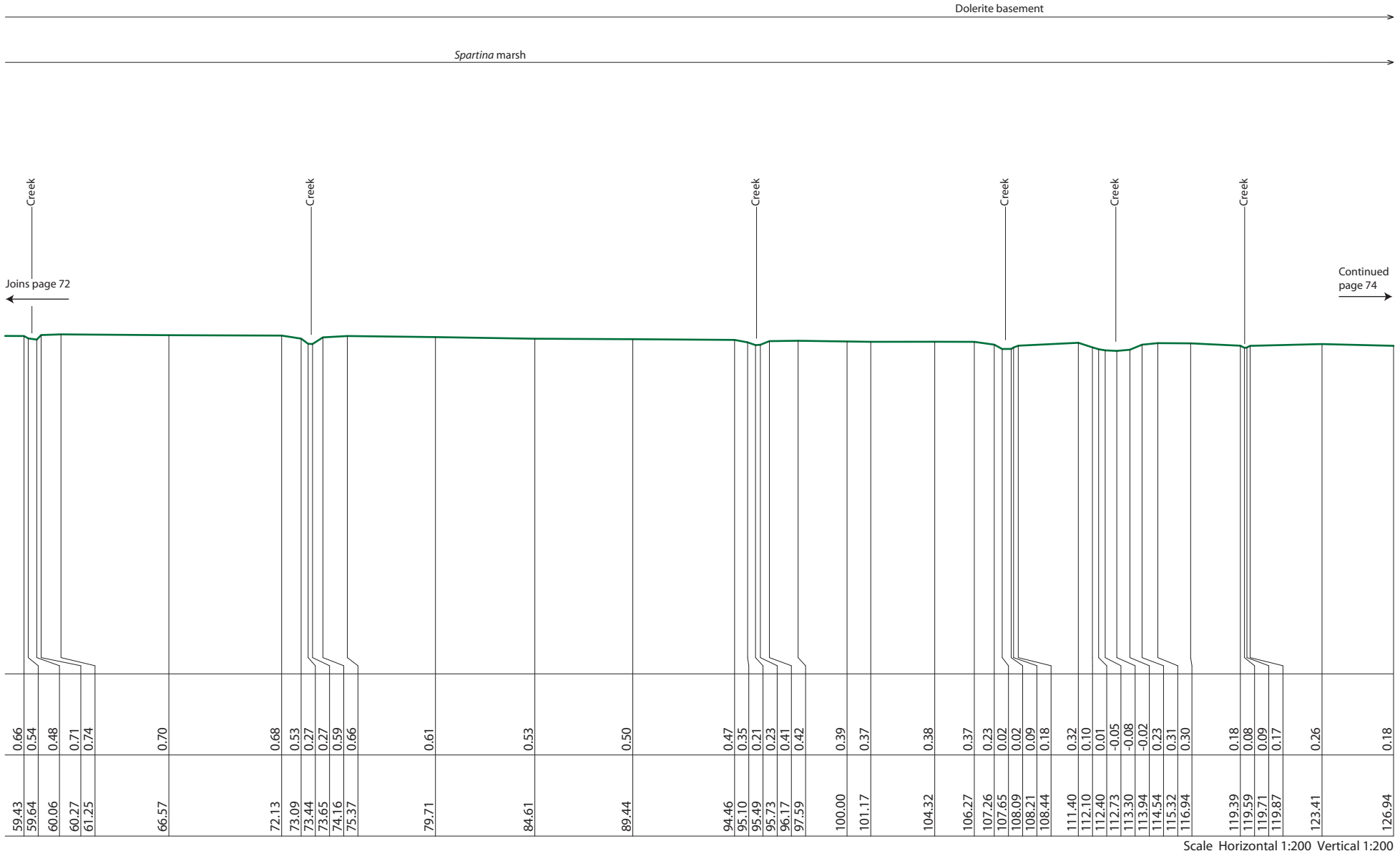


Figure 4.14: Section 2 of 4, Profile E10, Hillwood.

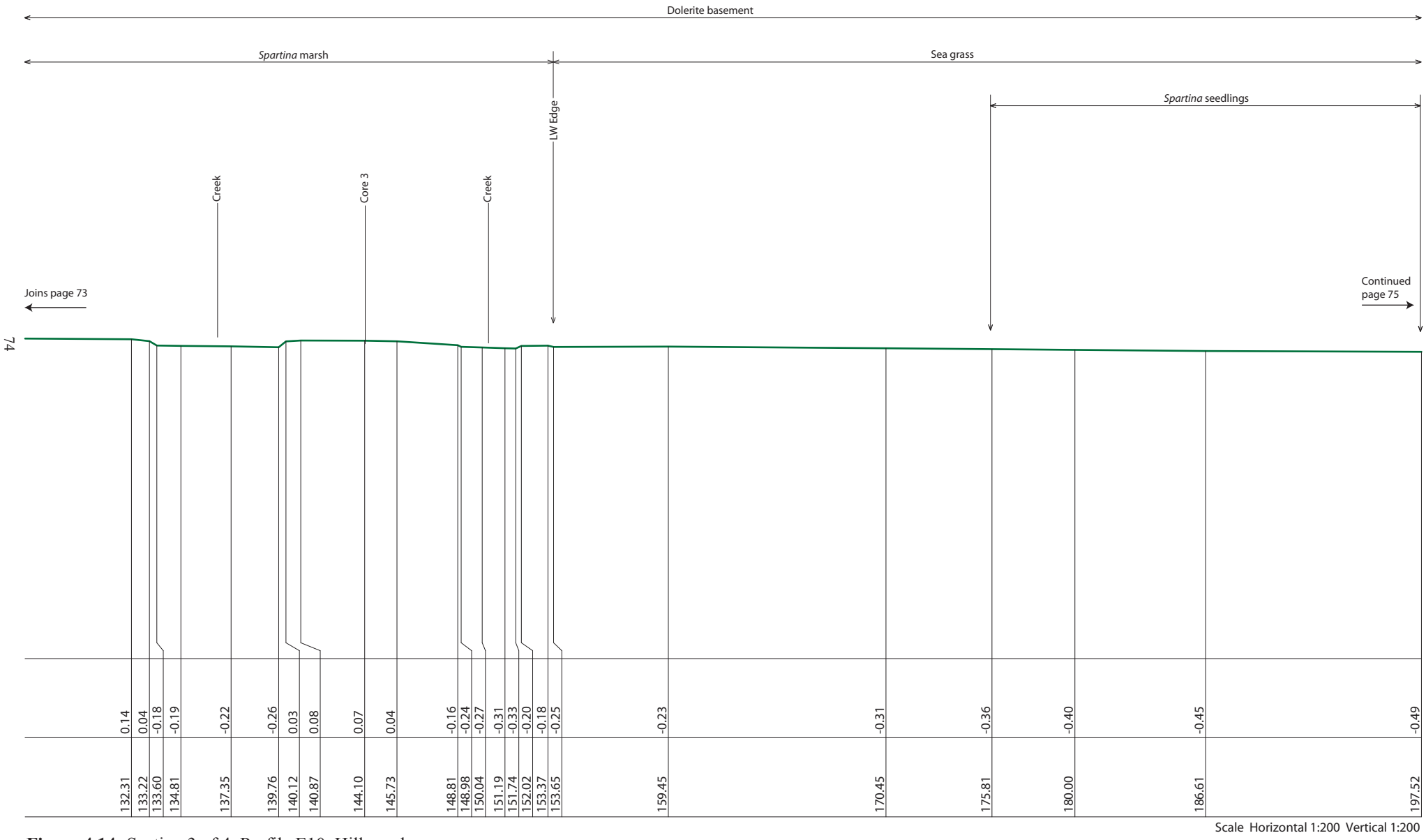


Figure 4.14: Section 3 of 4, Profile E10, Hillwood.

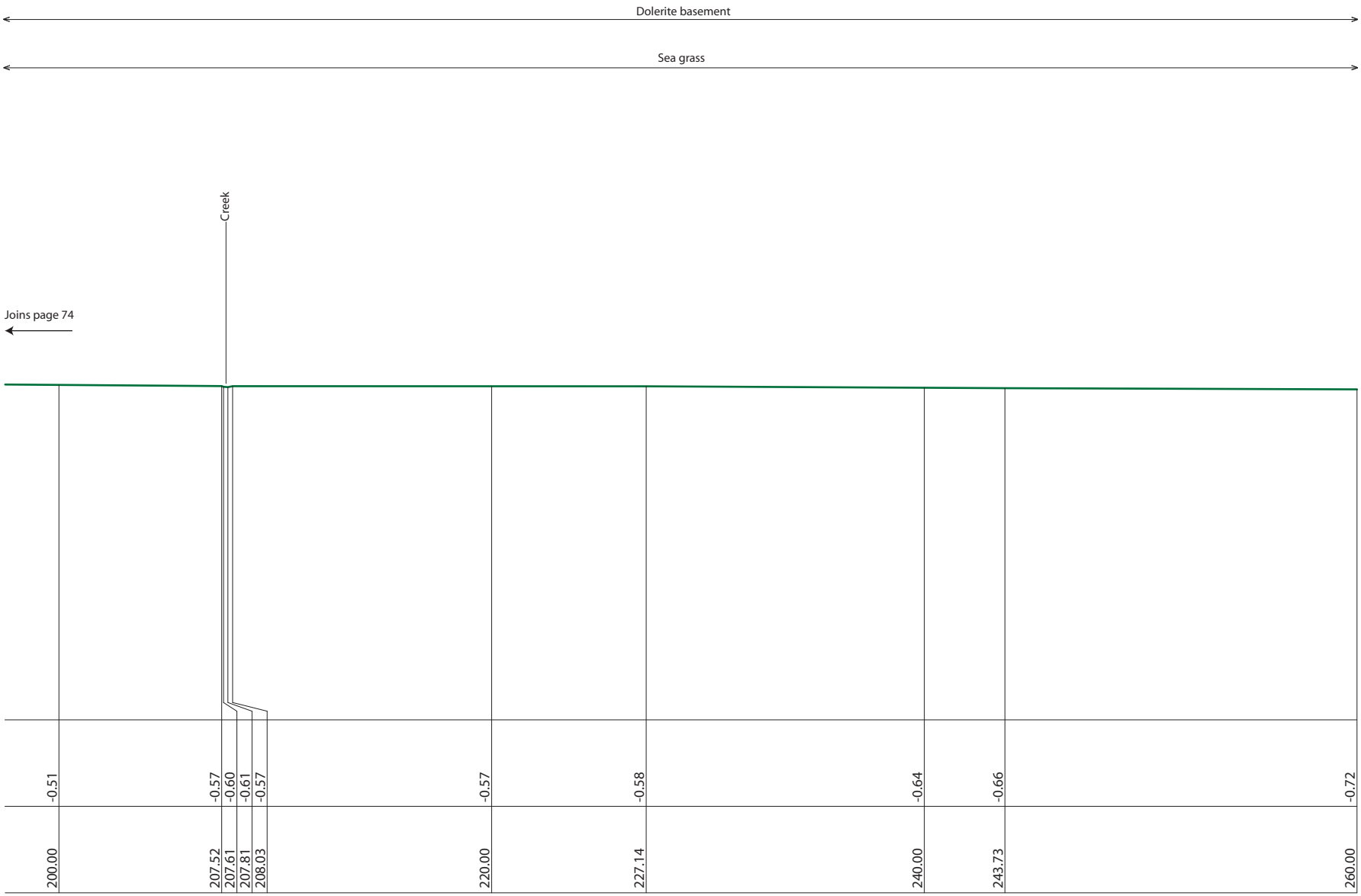


Figure 4.14: Section 4 of 4, Profile E10, Hillwood.

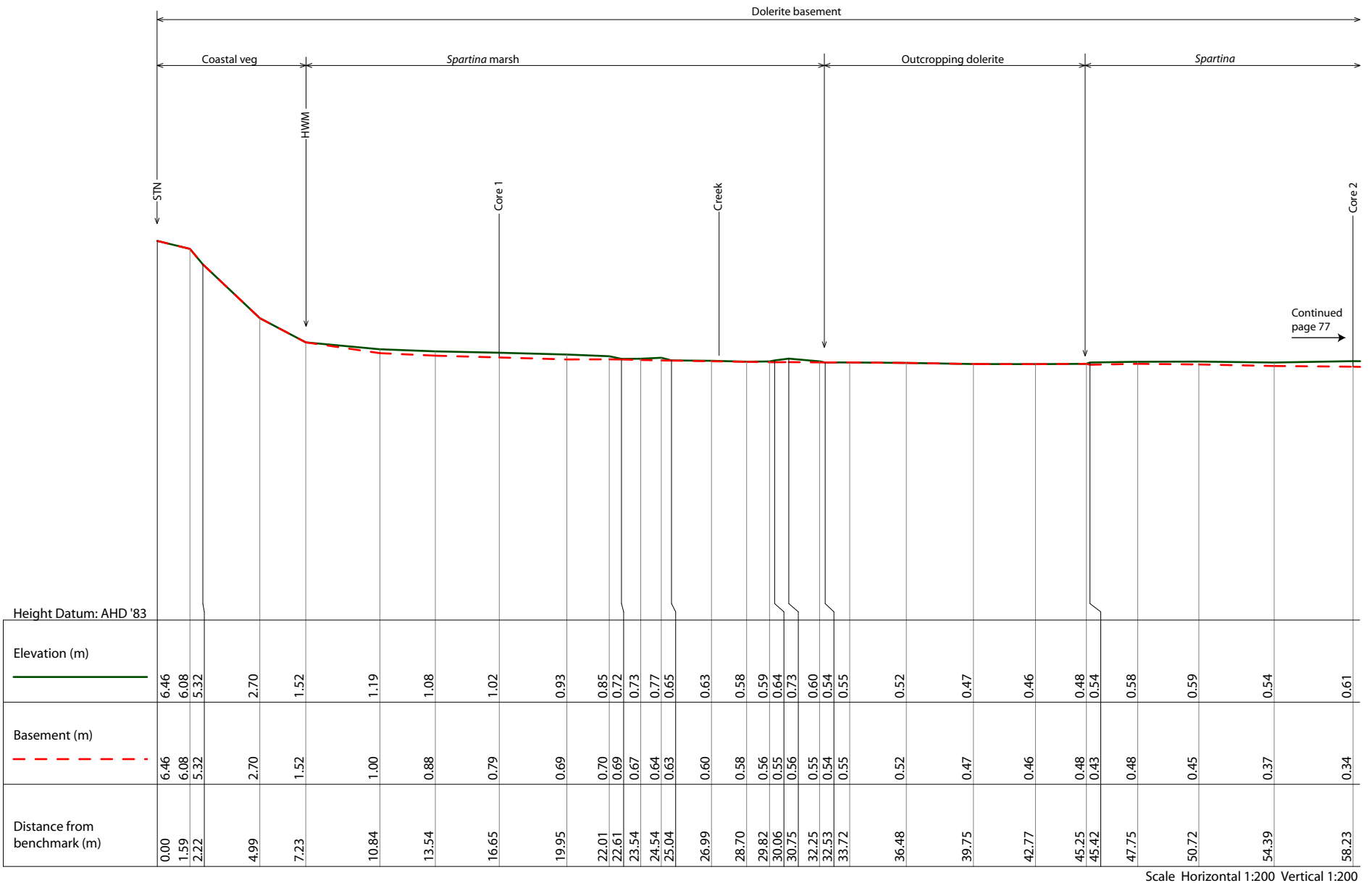


Figure 4.15: Landward portion of surveyed intertidal zone at Profile W16, Deviot.

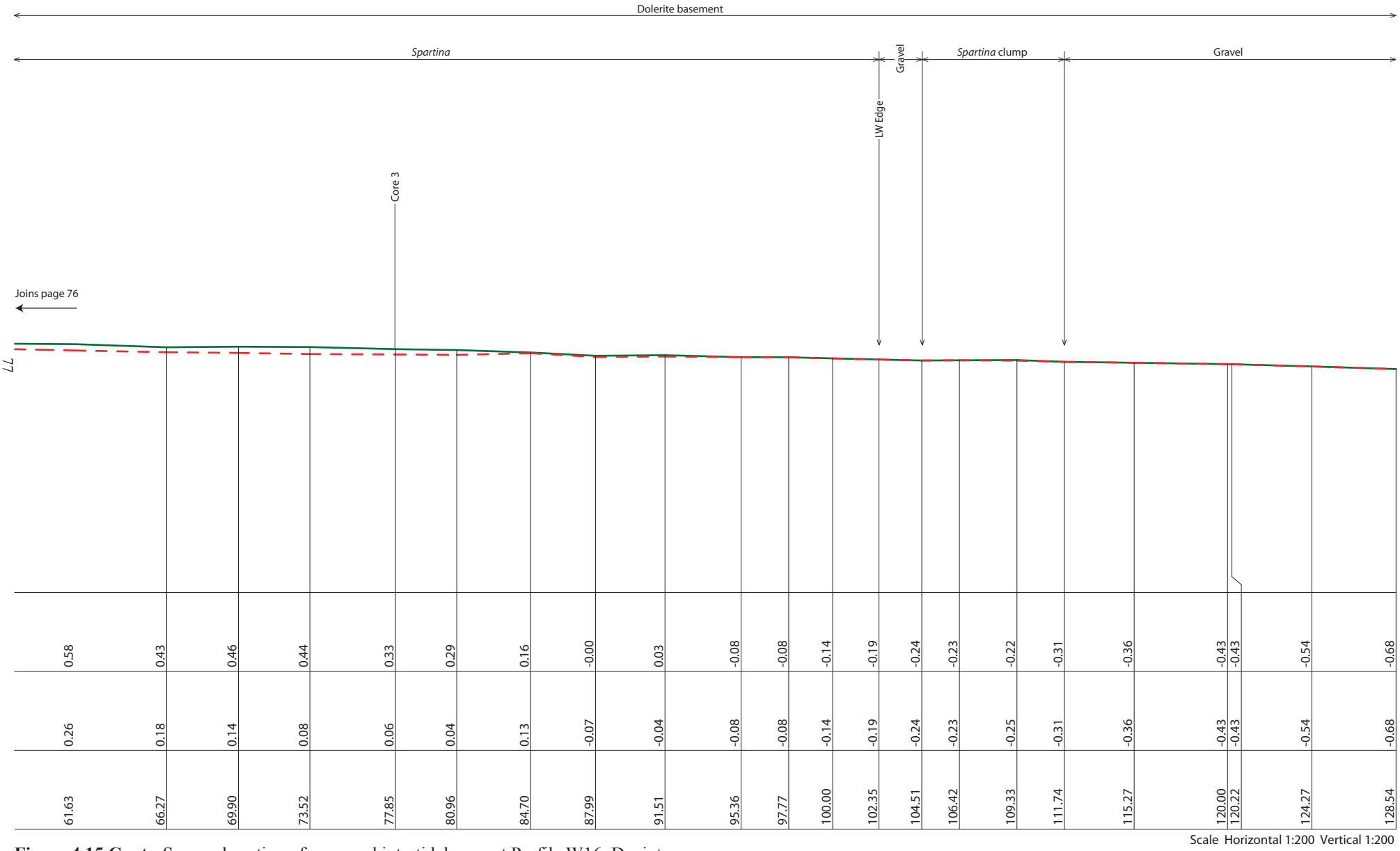


Figure 4.15 Cont.: Seaward portion of surveyed intertidal zone at Profile W16, Deviot.

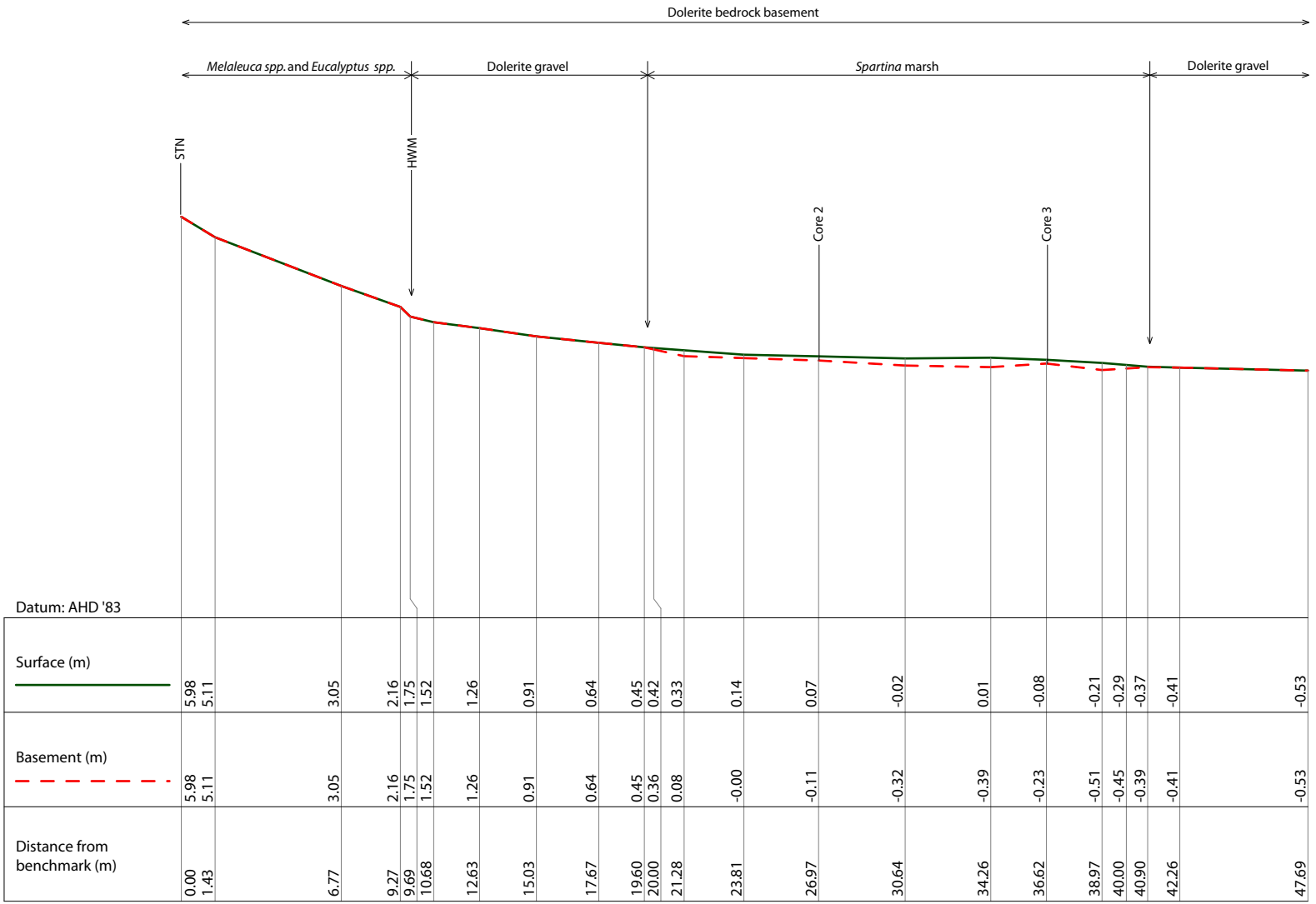


Figure 4.16: Surveyed intertidal zone at Profile W17, Deviot.

4.1.2 Seaward margin of *Spartina* marshes

The outer margin of type-1 *Spartina* marshes are strongly defined and all marked by erosional scarps and microcliffs of up to 2 meters as shown by the cross sectional profile of the outer edge of transect W01 (Figure 4.17a). The seaward margin shows severe undercutting and a tensional break developing behind the scarp due to the weight of the unsupported surface (Figures 4.17a, and b). This ultimately results in the failure and recession of the leading edge of the marsh (Figure 4.17c) and is referred to as beam failure (Schwimmer, 2001). In contrast, type-2 marshes continue to prograde seaward, exhibiting outer edges that are laterally poorly defined, often with isolated clumps and little change in relief at the interface between the outer marsh surface and the lower intertidal zone (figure 4.18). Progradation of type-2 marshes occurs by the coalescence of pioneering clumps or 'clones' on the mudflats seaward of the established swards (figure 4.18c).

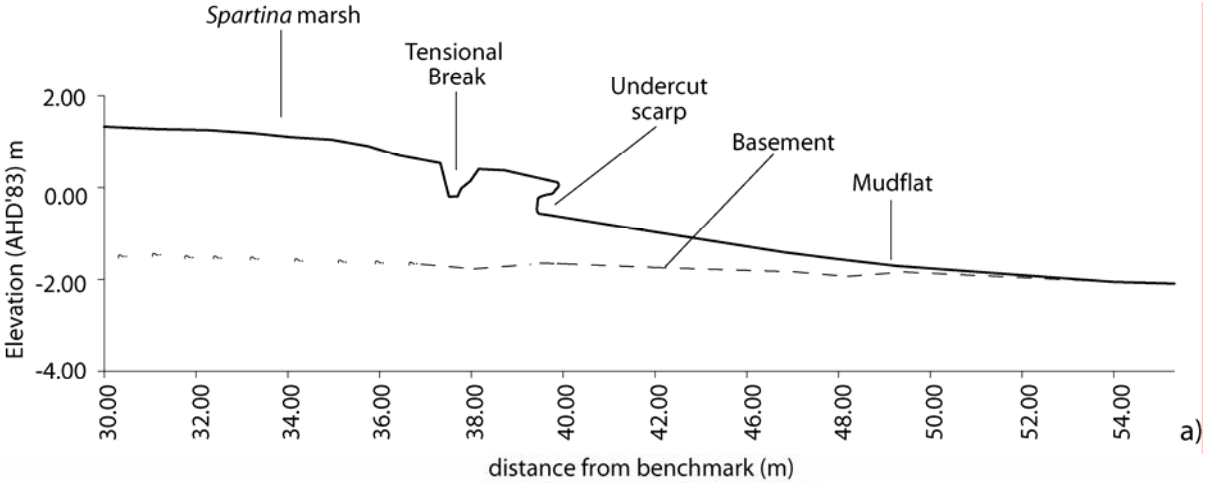


Figure 4.17: a) & b) Cross sectional profile of the seaward edge of the Legana profile (W01) showing undercutting of the outer edge. The weight of the over-hanging marsh creates a tensional break in the marsh, shown diagrammatically in **b)**, ultimately leading to beam failure and recession of the marsh, **c).**

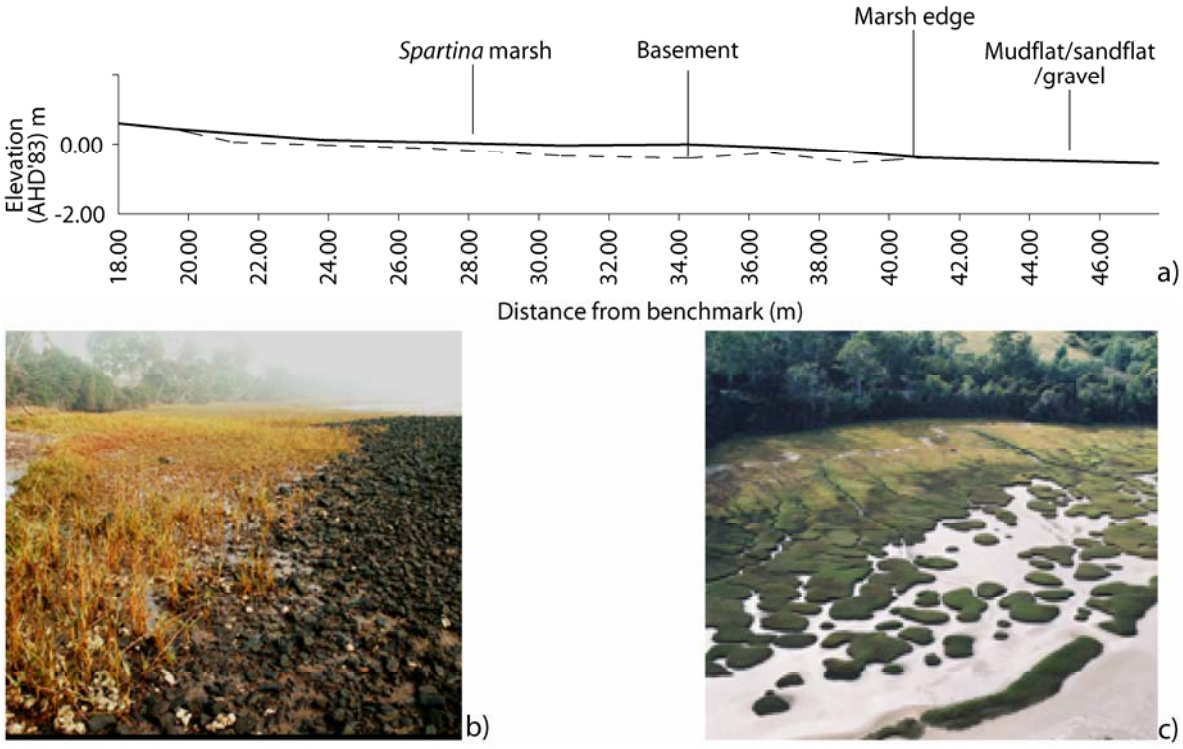


Figure 4.18: A *Spartina* marsh of the lower estuary (type-2 marsh). The profile diagram (a) and the photo b) show that the outer edge of type-2 marshes are poorly defined and have little elevational difference between the marsh and the lower intertidal zone. c) Marshes prograde by the coalescence of isolated 'clones' seaward of the main marsh. In the foreground a sand spit/bar has been colonised by *S.* anglica.

4.1.3 Temporal change in marsh cross sectional profiles

Figure 4.19 to 4.21 show surveys of *S. anglica* marshes from Rosevears, Windermere and Swan Bay respectively, superimposed on the original surveys from each location previously surveyed by Phillips (1975) and Pringle (1993). The Rosevears survey is opposite the original *S. anglica* planting site at Windermere and is a well developed marsh in a small embayment (Figure 4.19a & b). The overall marsh surface is concave-up, which has become less pronounced over time, approaching a flat surface by 2006. The survey of 2006 is substantially more detailed than that of previous surveys, showing the channel networks that dissect the marsh and the strongly concave-up marsh surface elements between channels in the mid and outer marsh. While there has been little change to marsh surface topography between 1989 and 2006, accretion has occurred, resulting in an increase in marsh elevation of approximately 20 cm. Between 1972 and 1989 the outer edge was a steep vegetated ramp, which remained stable and presumably graded into mudflat. It was found that by 2006 the outer edge had retreated some 15 m and developed a microcilff of approximately 1.5 m in height.

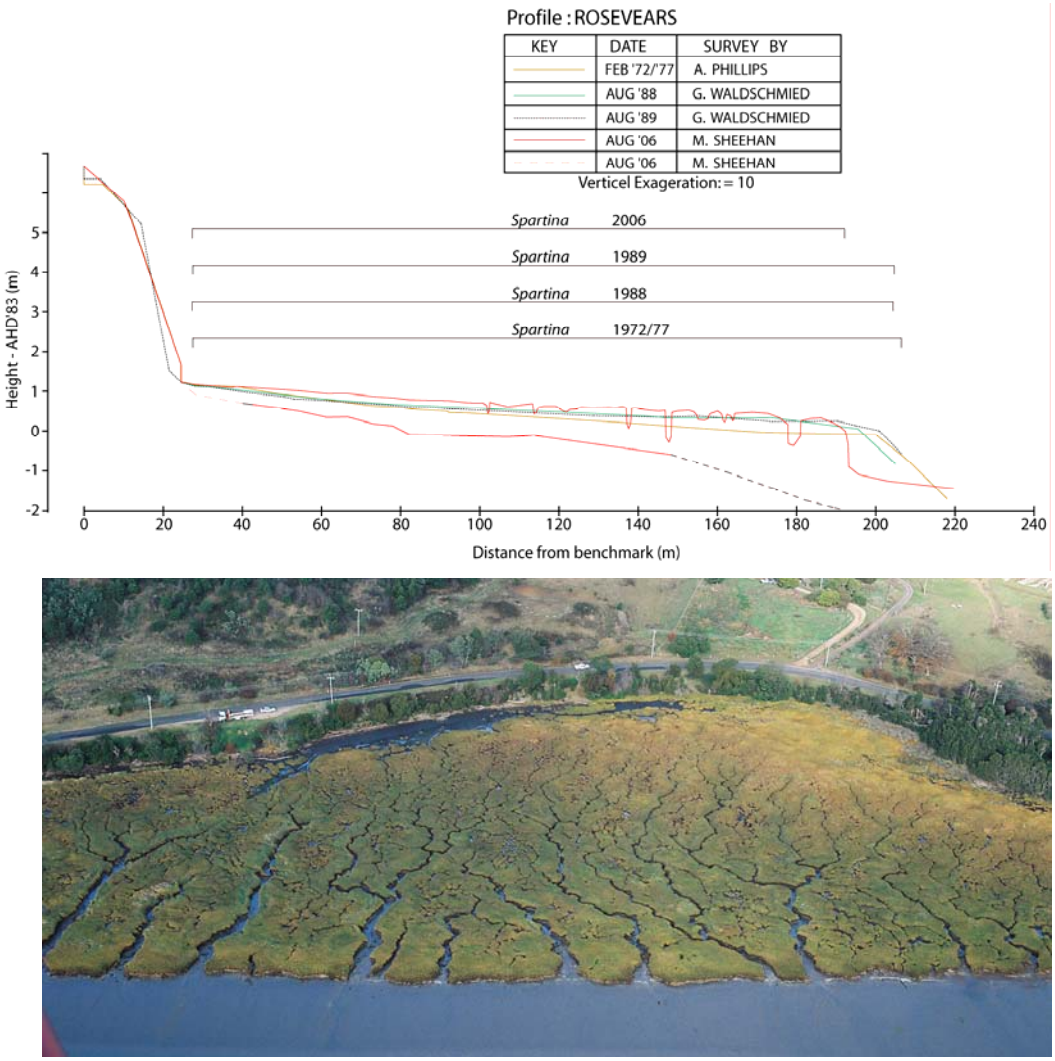


Figure: 4.19: a) Cross sectional profiles of the Rosevears marsh (W06) showing surveys conducted in 1972, 1977, 1988, 1989 and 2006. The substratum is also indicated. The marsh has accreted over time, yet has retreated in the past 17 years and developed a microcliff at the seaward margin, marking the limit of *Spartina* growth. b) Oblique aerial photograph of the Rosevears marsh with the transect indicated (Photograph M.R. Sheehan).

The Windermere profile (Figure 4.20) occurs near the original 1947 *Spartina* introduction site. Over the past 17 years since the first survey, there have been significant changes to the landward portion of the transect, which include road realignment, land filling and levelling. Modifications to the intertidal zone have also occurred in close proximity to the transect, and include the construction of dykes, a high water rock wall, and a pontoon. Physical removal of marsh sediment in an attempt to control further spread of *Spartina* has also been carried out nearby. While these factors may have influenced marsh development, temporal changes to surface topography, elevation and edge retreat along the profile are consistent with those observed at Rosevears. Erosion has been limited to the seaward portion of the marsh while deposition has occurred in the upper marsh, producing a terraced profile. Marsh retreat of approximately 10 m occurred between 1983 and 2006, with the removal of the lower marsh

and mudflat, exposing the dolerite boulder beach seaward of the 0.4 m microcliff. As with the Rosevears marsh, these changes have occurred since 1989.

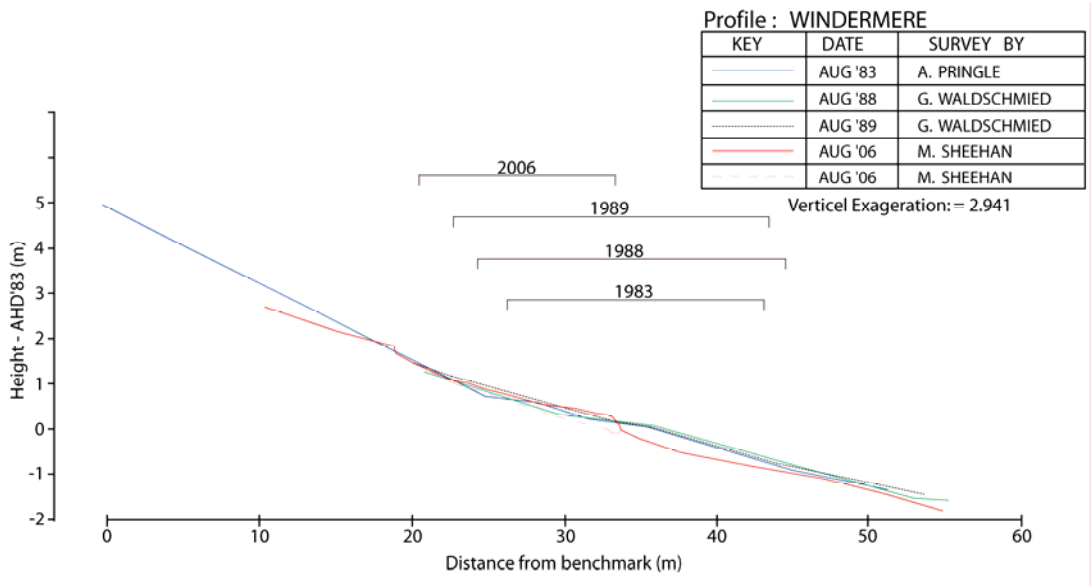


Figure 4.20: Cross sectional profiles of the Windermere marsh (E05) showing surveys conducted in 1983, 1988, 1989 and 2006. The substratum is also indicated. Spartina cover has extended to HW in the past 17 years, while the outer marsh and seaward extent of *Spartina* has retreated approximately 10 m. A microcliff has developed at the seaward margin and the dolerite boulder beach exposed seaward of the sward.

Swan Bay (Figure 4.21) is typical of type-2 marshes of the lower estuary. It occurs on outcropping basalt flanked by extensive mudflats. Accretion of approximately 5-40 cm occurred across the transect between 1983 and 1989, however there has been little elevational or morphological change to the marsh since 1989, with the exception of the upper marsh where some accretion has occurred, resulting in the formation of the characteristic terrace form of *Spartina* marshes. In the upper marsh, *Spartina* cover was estimated to be between 70 and 100 percent, decreasing to 20 percent in the outer marsh where *Spartina* growth was restricted to fractures and depressions in the outcropping dolerite where fine sediment had accumulated. There has been little sedimentation and negligible change to morphology or elevation in the lower marsh since 1989. Over this period however, that there has been retreat of approximately 11 m of the seaward edge of *S. anglica*, as well as landward expansion to the base of the sea wall.

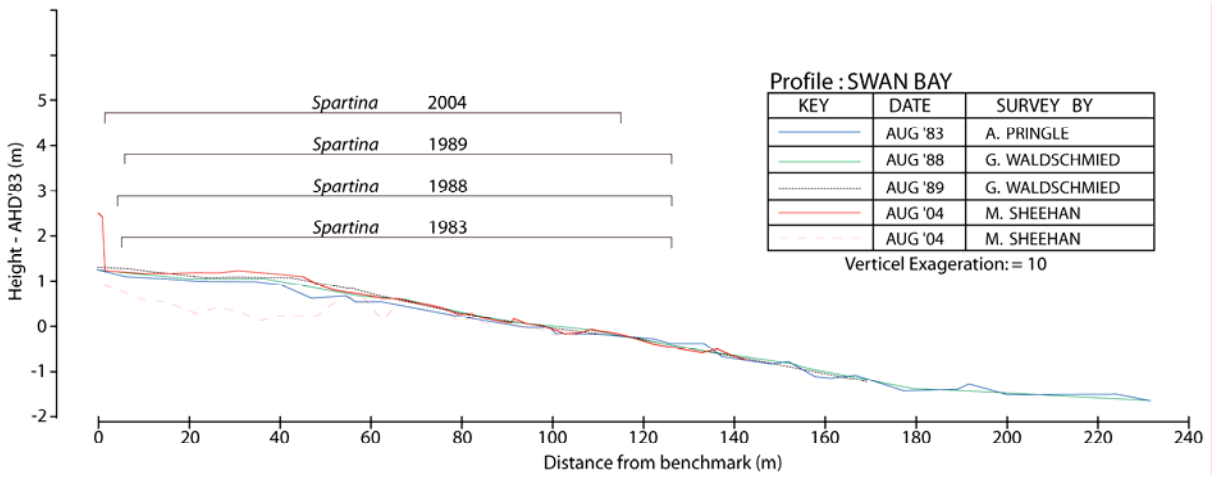


Figure: 4.21: Cross sectional profiles of the Swan Bay marsh (E08) showing surveys conducted in 1983, 1988, 1989 and 2004. This is a typical Type-2 marsh, which has experienced little topographic change since 1983. The seaward extent of *S. anglica* has however retreated since 1983.

Marsh width and the extent of *S. anglica* cover has decreased to a similar extent in each of the three profiles since 1989, with retreat of approximately 15 m, 10 m and 11 m at Rosevears, Windermere and Swan Bay respectively. Marsh width remained relatively constant in the 17 year period between 1972 and 1989 at Rosevears, and in the 6 year period between 1983 and 1989 at Windermere and Swan Bay.

5 Interpretation of Data

5.1 Morphology of Spartina marshes.

The following discussion is limited to what can be concluded about bank erosion demonstrated by these initial profiles. A comprehensive discussion on marsh morphology can be found in Sheehan, (In review).

5.1.1 Marsh surface morphology

The main differences in marshes throughout the estuary were apparent in marsh edge morphology and the degree to which the marsh surface had increased vertically relative to the substrate. Type-1 marshes, located upstream of Gravelly Beach have increased vertically to a greater extent than type-2 marshes of the lower estuary, and microcliffs at the outer margin indicate that marshes do not continue to prograde seaward. Conversely, type-2 marshes are less vertically developed and continue to prograde seaward, exhibiting outer margins that are poorly defined, often with isolated clumps and little change in relief at the interface between the marsh and the lower intertidal zone.

The upper and lower estuary differs geomorphologically in that the latter is significantly wider with extensive sandflats seaward of the marshes, and a deeper main channel. Sediments trapped within type-2 marshes are fine grained, yet overall local sediment is much coarser. Type-2 marshes are therefore most likely to be dependent on the transport of fluvial sediment or redeposition of marsh and mudflat sediment from the inland reaches. It is suggested that sediment supply may be the major factor limiting marsh development in the lower estuary because fine sediment is less available, possibly due to the deeper channel depths and improved flushing. In addition, the extensive sand flats and shoals are likely to attenuate tide and wave energy, reducing deposition of fine sediments in the upper intertidal zone where *S. anglica* marshes establish.

The results of this study with respect to marsh morphology strongly support the findings and conclusions of Phillips (1975) and Pringle (1993), and extends and updates the existing knowledge of morphological development and stability of marshes within the Tamar Estuary, Tasmania. Overall, the observed morphology of the profiles is explained well by French-Stoddart's Model of saltmarsh development (French and Stoddart, 1992; French, 1993; Allen, 2000) as shown in Figure 5.1 Using this model, marshes throughout the estuary can be classified as youthful, in the late stages of their development. Marshes are overall flat to slightly convex up, with concave up elements in heavily dissected marshes due to the formation of levees at the edge of creeks.

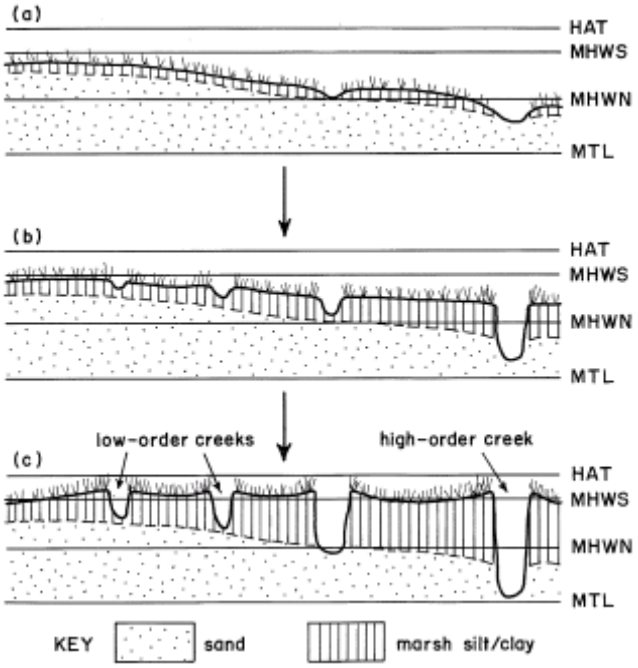


Figure 5.1: French and Stoddart's model of saltmarsh development from Allen 2000. (a) A marsh in early youth with precursor sandflat deposits below. The concave-up surface slopes seaward and is comprised of concave-up platform elements separated by a low density of small creeks. (b) Marsh in later youth. Platform elements flat to concave-up with an increased density of creeks deepening by erosion at the channel floor. (c) Mature marsh horizontal overall and with concave-up platform elements. A high density of well-developed, leveed creeks, the larger reaching deep into the precursor tidal flat sands.

Geomorphic features have been used extensively worldwide to assess the stability of intertidal marshes(Kirby, 2000; Schwimmer and Pizzuto, 2000; Schwimmer, 2001; Kirby, 2002). Of particular interest here is the finding that the marsh surface throughout the Tamar Estuary can be described as stable and depositional based on Geomorphic indicators, and is supported by the finings of the historical surveys form Rosevears, Windermere and Swan Bay (refer to section 5.1.3).

5.1.2 Seaward margin of salt marshes

While all profiles displayed a stable and depositional marsh surface, erosional features are wide spread in the outer margins of marshes on the upper estuary. Microcliffing and severe undercutting have lead to beam failure as described by Schwimmer (2001) resulting in marsh retreat. Historical profiles show that both cliffing and marsh retreat have occurred in the upper estuary within the last 17 years.

A limitation of total station surveying in this application is that it cannot record undercutting, and is therefore not shown on the profiles. Future surveying should possibly consider

measuring and recording undercutting as it was observed at the seaward edge of marshes at all transects upstream of Gravelly Beach. Lack of erosional features such as microcliffing and undercutting in the outer margins of type-2 marshes is most likely due to insufficient vertical development of these marshes combined with the attenuation of wave energy in the comparatively wider estuary and intertidal zones.

In an experiment designed to link bank erosion rates with easily measured wave characteristics in the Gordon River in Western Tasmania, within a boat-generated wave train a number of characteristics were measured and most showed a high correlation with measured rates of bank retreat (Nanson et al., 1994). Maximum wave height within the train is the simplest measure and is associated with a major threshold in erosive energy on unconsolidated sandy alluvium at wave heights of 30 to 35cm. At maximum wave heights above 35cm all but the most resistant bank sediments erode. Reducing maximum wave heights to <30cm by limiting boat speeds, and reducing the frequency of boat passages, caused a dramatic decline in bank erosion along the river. Bradbury et al. (1995) found that the wash from high-speed tourist cruise launches caused erosion of the formerly stable banks of the lower Gordon River. Speed and access restrictions on the operation of commercial cruise vessels after introduction considerably slowed but did not halt erosion, which continued on the now destabilized banks. The mean measured rate of erosion of estuarine banks slowed from 210 to19 mm/yr with the introduction of a nine knot speed limit. In areas where cruise vessels continue to operate, alluvial banks were eroded at a mean rate of 11 mm/yr during the three-year period of the current management regime. Very similar alluvial banks no longer subject to commercial cruise boat traffic eroded at the slower mean rate of 3 mm/yr. The mean rate of bank retreat slowed from 112 to 13 mm/yr with the exclusion of cruise vessels from the leveed section of the river. Revegetation of the eroded banks proceeded slowly; however, since the major bank colonizers are very slow growing tree species, it is likely to be decades until revegetation could contribute substantially to bank stability.

Foster et al. (1986) predicted that increased recreational boating on the Tamar would lead to mudbank erosion and sediment re-suspension. In a qualitative study of bank erosion in the Tamar Estuary, Gill and Blake (2002) attributed the erosion of the upper Tamar Estuary to boat wakes caused by a twin engine catamaran which has run as a tourist cruise boat for the past 10 years. While this is a likely cause, there are several other factors that must also be considered.

Localised marsh retreat can be caused by changes to estuarine hydrology, such as the lateral migration of tidal channels which undercut the seaward edge of marshes (Bird, 2000), while larger scale retreat of marshes is often attributed to coastal subsidence, particularly along the

south west coast of the UK (Strong and Ayres, in press) and the Louisiana coast (Ford et al., 1999).

There is certainly a potential for the predicted increase in relative mean sea level to outpace marsh development where sediment inputs are insufficient to maintain marsh elevation (Chung, 1994; Moorhead and Brinson, 1995; Cahoon et al., 1996; van Wijnen and Bakker, 2001; Rogers et al., 2006). This would result in further retreat of marshes and increased coastal erosion. However recent estimates of sea level rise taken from Port Arthur, Tasmania, indicate an average rate of sea level rise, relative to the land and combining the effects of land uplift of 1.0 ± 0.3mm/year between 1841 to 2002 (Hunter et al., 2003). These results are at the lower end of the recent estimate of global average rise for the 20th century, and are therefore considered unlikely to explain the severity of bank erosion which has occurred in the Tamar Estuary over the past 17 years. Increased recreational use of the estuary is therefore the most likely explanation of bank erosion and warrants further consideration. Qualitative assessment of climatic data also suggests that the incidence of extreme weather events such as strong winds and storms have increase in recent years. Wind-induced waves coinciding with a high tide have the potential to cause significant erosion of marsh edges and high water banks. Quantification of this observation would be valuable.

5.1.3 Temporal change in marsh cross sectional profiles

Surveys showing temporal changes to marsh topography, morphology and *Spartina* cover from three profiles show accretion on the marsh surface, landward expansion of *S. anglica* up to HWM, yet a retreat at the seaward extent of both the marsh and *Spartina* cover of 15, 10 and 11 m at Rosevears, Windermere and Swan Bay respectively since 1989. Historical profiles at Rosevears and Windermere (Phillips, 1975; Pringle, 1993) show a vegetated ramp at the seaward edge (Figures 4.19 and 4.20). Erosion of the outer edge and subsequent marsh retreat has therefore only occurred in the last 17 years. Prior to 1989 the lower edge fluctuated between progradation and retreat, with a net retreat of 5 m at Rosevears, no change at Windermere and a net seaward expansion of 5 m at Swan Bay (Pringle, 1993). The absence of survey data from the past 17 years makes it difficult to conclude whether the seemingly large and consistent values of edge retreat in 2006 indicates a long-term trend of marsh reduction, or if it is simply part of the oscillating cycle controlled by variations in tidal conditions and river discharge as predicted by Pringle (1993). Future monitoring will determine if marshes are in a phase of retreat or have established a new equilibrium with current hydrological forcings within the Tamar Estuary.

5.2 High Water Bank Stability

This study has focused on changes to the surface and seaward margins of *S. anglica* marshes throughout the Tamar Estuary. There is however an increasing concern over the stability of high water banks at the landward extent of the intertidal zone. The importance of these landforms has become increasingly apparent over the course of the *Spartina* project, and is therefore briefly considered here.

Spartina spp. are well recognised for their ability to provide a buffer to coastlines by attenuating wave and tidal energy, and hence have been used widely to provide coastal protection (Chung, 1994; de Jonge and de Jong, 2002; Strong and Ayres, in press). It is likely that *S. anglica* marshes provide some form coastal protection to high water banks of the Tamar Estuary. However the presence of active scarps in the HW banks throughout the Tamar Estuary, both in sectors where *Spartina* marshes occur and where they are absent, suggests that process other than marine and estuarine are at play. Terrestrial process often play a role in coastal and estuarine bank erosion, particularly along populated or industrialised coastlines.

Figure 5.2 Shows severe erosion and undercut banks of the foreshore between Little Swan Point and Swan Point. The shoreline above HWM along this section of the estuary comprises a thin organic rich peaty soil on which melaleuca-dominated coastal vegetation has established. This is underlain be a reclict intertidal zone of pebbles, course gravels and sands, formed during a period of higher relative sea level. During high rainfall periods, land runoff collects in depressions behind the relict shoreline and percolates through the gravels onto the upper intertidal zone, taking the finer material with it and depositing them on the marsh or mudflat below (Figure 5.3). This process is referred to as sapping and best explains the gradual retreat of the coastline and exposure of tree routes in this section of the Tamar Estuary. It is hypothesised that clearing of native foreshore vegetation, urban runoff and the development of hard built structures at high tide have exacerbated this natural process.

This is an example of one of many processes contributing to erosion of HW banks of the Tamar, and highlights the need for a comprehensive geomorphological assessment.

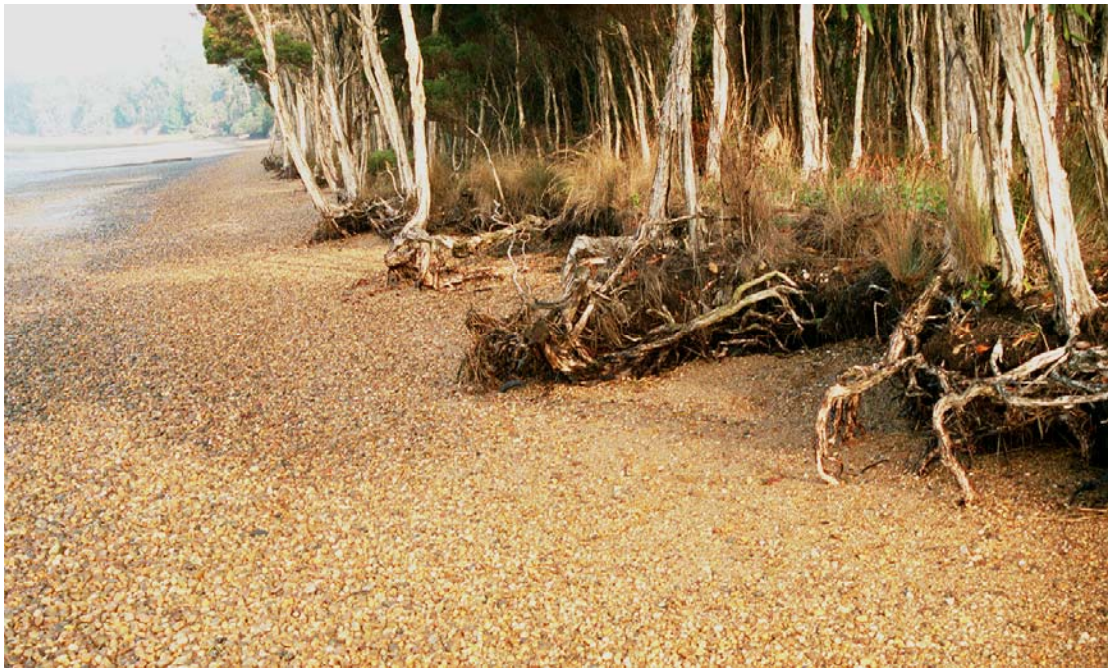


Figure 5.2: Bank erosion in a *Spartina* exclusion zone near Swan Point. The process of 'sapping' is likely to be the major cause of the erosion here rather than wave or tidal processes.

Figure 5.3: Sands and gravels are 'sapped' out of the high water bank by ground water and deposited as thin veneer upon the fine silts and clays of the Spartina Marsh near Little Swan Point. This process is likely to explain larger scale bank retreat observed between, Little Swan Point and Swan Point (figure 5.2.)

4 Conclusion

This study has demonstrated that the degree of morphological change to the intertidal zone of the Tamar has been significant since the introduction and establishment of *S. anglica* in the Tamar Estuary.

Two main marsh morphologies exist within the Tamar Estuary, differentiated from each other by edge type and the extent of vertical development. Marsh type 1 and 2 occur in the upper and lower estuary respectively, most likely brought about by the differences in hydrodynamic factors and sediment supply between the upper and lower estuary. Outer margins of type-2 marshes are most susceptible to erosional processes.

Retreat of the outer edge of *Spartina* marshes has accelerated in the past 17 years, most likely resulting from an increase in recreational boating in the Tamar Estuary and possible changes in climatic conditions such as increased incidences of extreme weather events. Both these likely causes require further investigation.

Erosion of HW banks both landward of *Spartina* marshes and where they are absent is of particular concern and likely to be exacerbated, if not caused by non-marine processes. Detailed geomorpholoical assessment of these Landforms and associate erosional processes is required to enable appropriate future management.

Cross-sectional profiles facilitate the assessment of the long-term stability of marshes. It is recommended that the profiles be re-measured every five years to allow quantification of long term change in marsh morphology and stability to guide appropriate management objectives.

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